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SOLAR ATTRACTION AND THE EARTH'S ORBITAL CENTRIFUGAL FORCE.

By Captain JOHN ERICSSON.

The accompanying illustration represents an instrument constructed for the purpose of proving by actual practical test, that the sun's attractive energy is balanced by the centrifugal force called forth by the earth's orbital motion round the sun. I desire it to be distinctly understood, however, that my intention is not to demonstrate what astronomers proved centuries ago, namely, that solar attraction is counteracted by the centrifugal force resulting from the orbital motion of the earth round the luminary. Léon Foucault, in his celebrated experiment of swinging a pendulum from the dome of the Panthéon, in Paris, simply intended to furnish ocular proof of the correctness of the assumption that our planet rotates round an axis at right angles to the equator. So with regard to the instrument under consideration, the object is simply to furnish *ocular* proof of the correctness of the assumption that the sun's attractive energy is counteracted by the centrifugal force developed by the orbital motion of the earth round the sun. My scheme consists in presenting a highly polished iron globe floating on the surface of mercury, to the sun at the moment of rising or setting, the terrestrial attraction being then exerted at right angles to the line of solar attraction, hence incapable of interfering with its action. Repeated experiments conducted with the instrument at sunrise and sunset, have established the fact that although a tractive force of a few grains is capable of moving the polished iron globe over the surface of the mercury, yet no movement whatever takes place when it is subjected to the pull exerted by the attraction of the sun, as stated. A brief description will suffice to explain the nature of the device. The illustration represents a section through the centre of the iron globe and the circular cistern which contains the mercury. Two spheroidal cavities, it will be seen, are formed in the globe, the upper cavity being empty, while the lower one is filled with a metal of much greater specific gravity than iron, the object being to retain the vertical axis of the floating globe in a fixed position. A movable ring is applied at the upper part of the mercurial cistern, admitting of a free rotary motion, while the cistern remains stationary. To the said ring an angular bracket is secured, supporting the central column of a delicate chemical balance. Obviously this arrangement admits of the balance being turned in such a direction that it points towards the rising or setting sun without disturbing the mercurial cistern or its contents. The lower end of the vertical index of the scale-beam is connected with the floating iron globe by means of a straight steel wire, as shown in the illus-

tration. This wire, extending beyond the vertical axis of the globe, has a small counter weight applied at its extreme end in order to relieve the balance from disturbing influence. To prevent dust from lodging on the mercury, a glass shade covers the cistern, resting in a groove at the upper part of the rotating ring, the shade also preventing currents of air from agitating the sensitive globe during experiments.

Regarding the experiments which have been instituted with the new instrument, it will be proper to observe that, although the energy of lunar attraction is practically imperceptible, it has been deemed best to conduct the observations when the moon is in the first quarter, its attraction being then exerted at right angles to the line of solar pull. Let us now consider whether these observations have been conducted on a sufficiently large scale to warrant definite conclusions. The diameter of the iron globe being 11 in., and its weight 181.47 lbs. avoirdupois, calculations based on the relative mass of the sun and the earth and other known data, show that the pull resulting from solar attraction amounts to 748 grains. The fact that the floating globe, while subjected to such a considerable direct horizontall pull, remains stationary, while a tractive force of a few grains suffices to produce motion, at once suggests the following question: Is the surface of the mercury in the cistern perfectly level in a line pointing east and west—does not solar attraction raise the surface of the fluid metal at the eastern edge of the cistern, thereby producing an inclined plane which solar energy is incapable of causing the iron globe to mount? This important question the writer has disposed of by the following device: Two open cisterns containing mercury, connected by a horizontal tube, are placed 20 ft. apart on a level stone foundation. Above the centre of each cistern a micrometric mechanism is applied, by means of which the height of the mercury may be measured with the utmost precision The two cisterns, with their connecting tube, being placed east and west, and time allowed for the mercury to come to a state of perfect equilibrium, the micrometers are adjusted. This adjustment, it should be particularly observed, is made when the sun is in the zenith, at which time its attraction evidently cannot disturb the equilibrium of the fluid metal in the connected cisterns. The contact of the micrometers and the mercury is then examined from time to time during the diurnal revolution, the final observation being made when, near sunset, the two cisterns point towards the luminary, at which moment the attractive force tending to disturb the equilibrium of the fluid metal, is at its maximum.

Regarding the result of the observations conducted P. M., it may be briefly stated that, when the micrometers are properly adjusted, not the least excess of elevation of the level of the mercury in the western cistern is produced by solar attraction at the moment when the attractive energy is exerted in the direct line of the two cisterns. Persons familiar with cosmical questions will say, that in case the sun and moon should be nearly in conjunction when the observation is made, lunar attraction will sensibly affect the equilibrium of the mercury in the cisterns. The relative energy of terrestrial and lunar attraction at the earth's surface being in the mean ratio of 320,600 to 1, a difference of level in the cisterns amounting to 0.000748 of an inch takes place under the stated conditions. Consequently this difference calls for a correction, after the adjustment at noon, readily affected by turning one of the micrometer screws through an arc of 8 deg. 40 min., the pitch being 32 threads per inch. The perfectly level state of the mercury in the cistern of the solar attraction instrument having been established by such accurate means, the absence of any motion of the floating ball when subjected to the pull of the rising and setting sun, furnishes positive *ocular* demonstration of the fact, that the sun's attractive energy exerted on the mass of the iron globe, is exactly balanced by the centrifugal force resulting from its orbital motion round the luminary. No reflecting observer, aware of the actual amount of the solar pull (748 grains), can witness the perfect repose of the floating iron globe, on the level surface of the mercury, at the moment when the sun is rising, without being impressed with the importance of what he beholds. Again, if he has previously calculated the curvature of the orbit in which the instrument is moving, he can assert that the velocity of the floating iron globe round the sun must exceed 18 miles per second, in order to develop by centrifugal action an energy capable of counteracting the pull which he *knows* the globe is subjected to while he is watching its repose on the surface of the fluid metal.

MODERN LOCOMOTIVES.

From "The Engineer."

On the 11th of November 1873, Mr. John Robinson read a paper before the Institution of Civil Engineers "On Modern Locomotives." Mr. Robinson, with great propriety, and for reasons which are very obvious to those who are acquainted with the commercial position which he holds, contented himself with describing various types of locomotives, refraining almost altogether from criticising their various qualifications as exemplified by the economical result of their performances. The paper was followed by a very animated discussion, however, which extended over two evenings besides that on which the paper was read. The paper and discussion have now appeared in the published Transactions of the Institution of Civil Engineers, and will no doubt be read with interest by a large number of engineers concerned in the working of railways. The impression which we formed while the discussion was in progress is, however, unfortunately confirmed by a perusal of the statements of the speakers as now put before us in a complete form. Mr. Robinson said, with much justice, "*Quot homines, tot sententiæ*—as many engineers, so many engines." Most of the leading locomotive superintendents of the kingdom were present, and took part in the discussion, which resulted in this, that one locomotive is just as good as another, and better. In short, it appears that, not only is diverse work done with success by the same class of engines, but that engines of the most varied types are employed with equal success to do the same class of work. It is not difficult, however, for any one possessing experience in analyzing evidence, and practically acquainted with locomotive working, to reconcile some of the apparently incongruous arguments of the speakers; or to find a means of piecing together opposing assertions of fact. But after all has been done in this way that can be done, much remains to prove that either we have yet a great deal to learn concerning locomotive performance and train resistance, or that the modern locomotive is the most accommodating machine in existence, all sorts of work coming alike to it, without any regard to its type, and with very little regard to its size; while the cost of running and repairs seems to be decided more by the quality of material and workmanship used than by anything else.

Let us consider briefly what some of the arguments of the speakers lead to. We find Mr. Stirling, of the Great Northern, arguing that single engines, with 8 ft. drivers, keep better time, and burn less fuel, and cost less for repairs than coupled engines; and this, be it remembered, on what is really a heavy line, with plenty of inclines, worked at an excessive speed. On the other hand, Mr. Price Williams argued that for the Great Northern traffic a coupled engine must be superior to any single engine, and he was supported by other speakers. Again, we find that Mr. Fowler maintains that engines weighing not less than 43¼ tons loaded could not work the Metropolitan traffic, while Mr. Webb, of Crewe, maintained that the work can be much better done by engines weighing but 32 tons; while Mr. Stroudley conducts a traffic quite as heavy, if not heavier than that of the Metropolitan Railway, at the same average speed—15 miles an hour—with engines weighing only 24 tons. Now, at first sight, it would appear that if any one of these gentlemen is right, the others must be wrong. Pursuing our examination, we find again that one engineer advocates the heating of the feed-water by the waste steam, and asserts that ten per cent. may be saved in fuel by such heating. But then another speaker tells us that he has been through the whole matter, and that there is no saving effected that is at all to be compared with the trouble and expense incurred. Again, we find the Le Chatelier brake extensively adopted by the Midland Company, while Mr. Webb states that he has tried it, and given it up because it cuts the cylinders. Then some engineers hold that brakes should be small, while others think they cannot be too large. These are but a very few of the points on which no two speakers could be found to agree; and, in a word, any engineering student who reads the paper and the discussion carefully will not know for some time afterwards whether he is on his head or his heels, and, if he is a youth of perspicacity, will infallibly come to the conclusion that locomotive designing is all a matter of rule of thumb, and that, as we have said, one engine is just as

good as another, and better. Let us see if this is really so, and endeavor to reconcile some of the conflicting arguments before us.

In the first place, it is evident, then, that a great deal that was said by each speaker has no more solid foundation in fact than the speaker's own opinion. A less logical discussion never, perhaps, was carried on by a body of scientific men. In the second place, we find a plentiful scarcity of statistical information. It would be too much to say that the paper and discussion possess little or no real value as sources of information; yet it is nearly the fact. It is by no means easy to analyze the results of the performance of any given type of engine, and draw correct conclusions from a comparison instituted between this type and some other; yet without such a comparison it is impossible to arrive at a just conclusion as concerns their relative merits. Nothing of the kind worth the name was attempted during the discussion under consideration—at all events, in the shape of logical reasoning. We can find no better example than that supplied by Mr. Fowler's statements. Put into a nutshell, his arguments are, that no better engines, except in a few points of detail, can be designed for working the traffic of the Metropolitan Railway than those in use. But he did not even attempt to prove that he was right. As a matter of fact, he does not know whether they are or are not the best. No doubt he thinks they are the best, in all honesty, because he designed them. But Mr. Fowler is not a locomotive superintendent, and he lacks the practical experience of such a man; and when we find Mr. Webb, who is a locomotive superintendent of great experience, asserting that Mr. Fowler is wrong, while Mr. Stroudley, another locomotive superintendent, proves that he is wrong by carrying as many passengers at as high a speed, over as bad a road, with engines little more than one-half as heavy as Mr. Fowler's, we cannot help rejecting Mr. Fowler's conclusions as unwarrantable. On the other hand, however, we must not condemn Mr. Fowler too hastily. It will be seen that those who took part in the discussion curiously enough confined their attention almost entirely to the number of passengers carried, and estimated the utility of their locomotives in terms of passengers only. Now the fact is, that both Mr. Fowler and his opponents in doing this, totally overlooked a most important factor in their calculations. We do not believe that one of Mr. Stroudley's little engines would work an ordinary Metropolitan train with punctuality. We are on the side of Mr. Webb and Mr. Stroudley, and opposed altogether to the system of working the Metropolitan Railway introduced by Mr. Fowler; but our objections are by no means confined to the engines, but to the entire stock, which is quite too heavy and unwieldy for the duty. Mr. Stroudley's success with his small engines is due entirely to the beautiful rolling stock which those engines haul—stock, in our opinion, admirably suited to its intended purpose, which the Metropolitan stock is not. Another example of the want of logical accuracy, manifesting, we might say, a total oblivion concerning facts passing daily around him, is found in Mr. Fowler's statement that "it would never do to have a rigid engine with six wheels coupled to pass round curves of ten chains radius, or seven and a half chains radius." "He believed that no engineer had ventured on such a desperate step to increase the adhesion, as to couple six wheels of the engine for a line with sharp curves." These two sentences prove directly either that Mr. Fowler really knows nothing at all about locomotives, or that in order to support his own opinions he thought proper to manifest what is really dense ignorance. To go no further, we may point out that the Semmering incline is worked by locomotives, some with 6 and some with 8 wheels coupled, and that on it are to be found plenty of curves with radii of 5, 6, and even 3½ chains. In fact, no expedient is more common than the coupling of 6 wheels in the case of locomotives intended to work sharp curves. No one, so far as we are aware, ever proposed to work a rigid engine on such a line, except Mr. Fowler himself, who, if he would read a little more, would find that engineers are familiar with many devices for rendering engines as regards their wheel base flexible; as, for example, sliding axle boxes, the removal of flanges from driving wheels, and so on, all of which expedients are successfully in use.

The discussion gradually drifted away from metropolitan traffic to the relative merits of coupled and uncoupled engines. As regards the advocacy of the latter, Mr. Stirling stood almost alone; and as he represents a style of practice apparently rapidly becoming extinct, his observations de-

serve special attention. He stated that "he had constructed two classes of passenger engines, one class with 4 wheels, 6 ft. 6 in. in diameter, coupled; the other with a pair of 7 ft. driving wheels. Both engines had similar boilers, and cylinders 17 in. in diameter, with a length of stroke of 24 in.; the pressure of steam in the boilers was 140 lbs. On his frequent journeys from London, he had been in the habit of noting the size of the trains, and of the class of engine used. He found that with a similar train in both cases the single engine had fully the best of it, in fact generally beat the coupled engine in time to Potter's Bar, a distance of nearly 13 miles, and nearly all uphill, the gradients varying from 1 in 105 to 1 in 200. This led him to think that sufficient adhesion could be got with a single pair of driving wheels, and he believed no one would doubt the superior freedom and economy of a single engine over a coupled one. He then designed an engine,* the tractive power of which, by calculation, was 15 per cent. more than that of the coupled one, and in practice it performed proportionately more work. It conveyed trains of from 16 to 26 carriages from King's Cross, with ease, and on several occasions 28 had been taken and time kept. No doubt existed as to its running powers, a distance of 15 miles in twelve minutes having been accomplished with a train of 16 carriages. The engine had been perfectly satisfactory in all respects, and more of them were in course of construction. The average consumption of fuel, with an average load of 11 carriages, was 23 lbs. per mile. It might be said that a few pounds of fuel per mile was no great matter, but 1 lb. per mile on the Great Northern mileage per annum, represented a sum very little short of £5,000, and a few pounds would make up a large sum. The large engines were constantly employed on express trains, running from 45 to 50 miles an hour. It had been said the weight on the driving-wheels—15 tons—was excessive, and would be destructive to the permanent way; but such was not the fact as reported to him by the engineers of the line. The bogies in front carried a comparatively light load on each wheel, but quite sufficient to solidify the road before the driving wheels came on the rails, and thereby put it in the best position to carry the weight of the large wheels. The engines seem to have plenty of adhesion for the size and power of the cylinders, and did not slip more than coupled engines under similar circumstances; and, with a slight application of dry sand, slipping was entirely prevented. Powerful passenger engines were a necessity on the Great Northern Railway, from the undulating nature of the road, scarcely any part of the main line being level, and the ruling gradients were 1 in 200 throughout, except out of King's Cross, where there was a length of 1¼ mile, with a gradient of 1 in 105."

Now these are beyond question remarkable facts, deserving some attention, and in a great degree borne out by the success with which single engines work passenger traffic on the London and North-Western and Great Western Railways. We need not say that the use of coupled engines is rapidly extending, and that Mr. Stirling is perhaps the only engineer to a first-class line of railway who maintains that single engines are right and coupled engines wrong. However, the fact remains that his engines do their work as well as coupled engines. Are we to assume, then, that single engines must be better than coupled engines? We think not. It is just one of the peculiar defects of this discussion, however, that almost the only argument urged against single engines was that they lacked adhesion; but this was just the point on which Mr. Stirling was strong, because he proved by citing daily experience that whether his engines had or had not as much adhesion as though they were coupled, it was certain that they had all the adhesion they needed for the performance of the duties required of them. Indeed, to argue that if they had four wheels coupled they would have more adhesion was about as much to the point as a statement that if the engine had 4 ft. instead of 8 ft. wheels it would be able to haul double the load.

It is impossible within the limits of a single article to even touch upon all the questions raised during this discussion, or to disentangle the mass of conflicting statements put before us. We shall return to the subject. Meanwhile, we may re-explain, to impress the facts on the minds of our younger readers especially, that much of the apparent inconsistency of the various speakers on metropolitan traffic disappears the moment we comprehend the fact that they spoke of engines and passengers only, with

* Complete working drawings will be found in our portfolio, Nos. 47 and 48, 1871.

little or no regard for the weight of the rolling stock used by each engine in hauling a given number of passengers; while, as regards coupled and single engines, the speakers once again spoke on abstract principles, with little regard for the special work to be performed by the engines. Thus, it would be easy to show that with two pairs of drivers coupled—the trailing pair carrying the weight previously on the trailing wheels of the engine, a considerable increase of adhesion and attractive force might be had; while if the bogie wheels were also coupled, the whole weight might be utilized for adhesion. If, however, no more adhesion is required than one pair of wheels will supply, it is useless to argue in this way, and the relative merits of coupled and single engines must be decided on a very different basis.

METHOD OF DEEP-SEA SOUNDING BY MEANS OF PIANO-FORTE WIRE.*

From "The Telegraphic Journal."

The great merit of wires compared with rope is the smallness of the area and the smoothness of the surface which the wire presents, as compared with the greatness of the surface and its roughness when rope is used with a comparable degree of strength. The wire that I have found suitable is piano-forte wire of the Birmingham gauge No. 22. It weighs about 14½ lbs. to the nautical mile, and bears from 230 lbs. to 240 lbs. pull without breaking. The quality of wire which I described to the meeting of the British Association at Brighton was special wire made for the purpose by Messrs. Johnson, the celebrated wire-makers at Manchester. They succeeded in producing a length of three miles in one piece of crucible steel, which certainly was a very great feat in the way of wire-making; and this wire was presented by them to me as capable of bearing a strain of about 230 lbs. I tested many specimens of it, and I found that none of them broke with a less strain than something like 220 lbs., and that many of them bore as much as 240 lbs. The wire then fulfilled all that the makers promised, and it had that quality which then seemed of paramount importance, a great length in one piece of metal. The truth is, that one of the impossibilities was splices. I tried splices in first experimenting in this process, and by making a twist of two pieces of wire together in a somewhat long lathe, and running solder all along the interstices, I made a very good splice. However, on testing this splice, I found that, although it would bear within 10 lbs. or 20 lbs. of the full weight of the wire, yet in every case of a pull with longitudinal force, the wire broke. This was precisely in accordance with theory. In fact, I always found that this was the case. The result never differs from theory; that is to say, the theory is correct. The sudden change of area of set between the long cylindrical wire and the thickening produced by the solder is an essential element of weakness. That is a general character which is well known to engineers. Inevitably, if the wire is of uniform character, it breaks close opposite the solder. To avoid this weakening of the wire, an exceedingly gradual commencement of the pressure or force by which one piece of wire is connected with the other must be attained. The obvious way of obtaining this is by a very long splice. A splice of 2 ft. long I have found quite sufficient. The splice I may describe shortly. The two pieces of wire to be spliced are laid, with one coinciding, approximately, 2 ft. with the other. At the middle of the lap, one wire being held out firmly, 1 ft. of the other wire is laid down with a very long spiral lathe. Then, turning to the other side, 1 ft. of the other wire is laid down in a lathe of the same quality. That is to say, there is a right-handed screw on each side. The wire has been previously coated with marine glue, just to increase a little the surface friction. The wires are found to cohere perfectly when splices are made in that way, all that is necessary to make the splice permanent being to cover the ends over for about an inch with a serving of twine just to keep the ends firm down. I have tested scores of splices made in this way; and in no one instance did the wire break in the splice or near to it. It always

*Read before the Society of Telegraph Engineers, by Sir Wm. Thomson, F. R. S.

broke some distance away, showing that the wire close to the splice was as strong as the other part of the wire; and of course in the splice itself the two wires together give a greater strength than exists anywhere else. The difficulty with regard to splice being altogether got over, we are freer in our choice of the wire to be used; and, accordingly, upon the advice of Mr. Johnson himself, I went on sounding with piano-forte wire. Therefore I have been driven back to that, and I find that it is of much better quality than other wire. Mr. Johnson tells me that it is impossible to produce in other kinds the same quality of wire as is habitually made by the best makers of pianoforte wire. He said that although he could produce wire of great strength, he found it impossible to attain the same temper as that of the piano-forte wire. Acting upon his valuable advice with respect to the quality of wire, I have now begun to use altogether the best quality of piano-forte wire. That which I now adopt seems to fulfil all the qualities we look for in a material. The first difficulty, and one which seemed in the first place an insurmountable difficulty, was the tendency of the wire to kink and break. The first thing is to endeavor not to let the wire kink, and, in the second place, if by any accident it does kink, it is desirable that it should not break. I found that the piano-forte wire, if pulled to a breaking strain, would stand, without breaking, a far greater strain than it was exposed to in any part of the sounding process; and, therefore, we felt greater security that even a bad kink would not be liable to break. The lengths which another firm supply of this wire are, I believe, 400 yards. You must take that with some reserve, but to the best of my memory 400 yards is the greatest length. But, however, a splice at 400 yards or 200 fathoms is no inconvenience whatever. The defect in the original apparatus to be remedied is in respect to hauling in by the whim—this wire wheel which you see. It is in the same form that I have used all along. That is the original form of wheel, and the process of hauling is simply to coil it up. The wheel is about a fathom in circumference. My first sounding was in water of 2,700 fathoms, in the Bay of Biscay; 100 fathoms was the deepest sounding marked on the chart. I made a careful sounding, so that there is no doubt about the figures. I found, in hauling in by winding it upon the wheel, that, after about 1,500 fathoms had been taken in, the wheel began to show very serious signs of distress. The wheel was perfectly round and symmetrical at first, and when there was still about 800 fathoms out, it assumed very much the shape of an old sea cocked hat, and I had great difficulty in getting in the last 800 fathoms; and therefore, of course, the wheel and the work were not perfectly related to one another. I have made various attempts to overcome the difficulty. My first attempt issued in failure. It consisted in stopping the process after a certain number of fathoms, say 20 fathoms, taking the strain off the wire, and easing it round the wheel. It was done in a sounding of 1,200 fathoms, made in Funchal Bay, Madeira, only a few miles from Funchal, during Hooper's cable expedition to Brazil last summer. I found that the process was, in the first place, exceedingly tedious. I found that stopping every 20 fathoms did not seem to be of any use at all, so I stopped at 10 fathoms, and it made a very long job in 1,200 fathoms, and besides, it did not afford sufficient accuracy. That plan being a failure, I then looked out for some other; and the peculiarity of the present apparatus consists in the way in which that difficulty was overcome. I may say that in the American navy another mode of getting over it has been followed. The wheel has been strengthened and the weight has been detached in the American soundings by wire. One of the trigger detaching apparatus has been used, and the weight has been reduced. That, of course, lightens the pull upon the wire very greatly. By those means—the strengthening of the wheel and the lightening of the pull—the Americans got over the difficulty very well. I, however, did not consider it desirable to throw away 30 lbs. or 35 lbs. of lead or iron at every sounding, and we found it well to do all we could, in moderate depths of 3,000 fathoms, to bring back the sinker; and if we got into the way of doing that in 3,000 fathoms, then we might be able to do it in greater depths. The Challenger failed in this respect, in taking soundings in the Gulf Stream; but by this process that which baffled the Challenger is made very easy. And there are greater depths, no doubt, than any which we have found. Perhaps we may have got near to the greatest depths. The Challenger has shown us 3,500 fathoms, but I think that it would be

rash to say that there are not depths of 5,000 fathoms. I should wish, therefore, to do all we can without throwing away our sinkers in depths of 3,000 fathoms. In the case of very great depths, we might, perhaps, take a heavier sinker and detach it. In the meantime we have no difficulty in recovering the sinker from a depth of 3,000 fathoms; and, having no difficulty, I prefer an apparatus which will in every case bring back the sinker. I will explain the method of doing away with the defect arising from the strain of the wire, experienced through having a heavy length of wire coiled up on the wheel, and a heavy pull. In the first place I shall describe the process of sounding from a ship hove to for the purpose of making the sounding, and I shall say a word or two in conclusion about flying soundings—soundings made without stopping the ship—which are of great importance in cable expeditions. But, in the first place, with regard to soundings when the ship is hove to, the sounding being the great object. Of course the ship is kept, as nearly as may be, at rest, and that is continued as long as is necessary for bringing up the wire and the sinker. The weight is attached by a piece of rope to a ring or clamp, the ring or clamp being attached to the wire. That is a first precaution which I introduced to avoid kinking. No matter how carefully the operation may be conducted, we never can be quite sure but that a little line will be allowed to run out after the weight reaches the bottom. If the wire was attached direct to the weight, the moment the weight reached the bottom there would be kinking; and that was one of the great difficulties. I have been told in our hydrographic department, "You need not try sounding by wire, for it is impossible! The wire goes over the rope, and the moment you try to pull it up it kinks." Therefore, instead of allowing the wire to become slack, in my first experiment I attached the weight to the clamp by 15 fathoms of cod line, and that clamp was attached to the wire. The clamp was about 4 lbs. weight. At present, in the apparatus now before you, there is a ring, weighing, perhaps ¼ lb., attached direct to the wire, but I believe that it will be advisable to add weight to that ring, because I think there may be some little risk of the wire becoming slack when the weight comes to the bottom, and I should not like to trust to the wire shooting through the water with no more weight than that upon it to keep it tight. Therefore I propose to add weight to the ring, so as to bring it up to 3 lbs. or 4 lbs. Well, now, of course everything depends upon the stopping when the weight comes to the bottom, because if you do not accomplish that, then the bugbear of the wire coiling on the bottom, and kinking when you draw it up, will be a reality. The mode by which I secured that there shall be very little more line paid out from the ship after the weight reaches the bottom, is simply this: A measured resistance is applied systematically to the wheel, which resistance is always to be more than enough to balance the weight of the wire out. Suppose, for example, we apply a resistance exceeding by 10 lbs. the weight of the wire out. The sinker which I have used is 30 lbs., the clamp 4 lbs. We have, then, 34 lbs. between the clamp and sinker. There is the resistance of 10 lbs. exceeding the weight of the wire out, and thus we have 10 lbs. off the 34 lbs. of the sinker and clamp. That is, we have 24 lbs. weight for the moving force. That, I have found, is amply sufficient to give a very rapid descent, a descent so rapid that certainly in the course of half an hour, or three quarters of an hour, the bottom would be reached even at a depth of 2,000 or 3,000 fathoms. Then, of course, there must be great care in paying out the wire. The person in charge must watch. We have a counter here for the time. You cannot see it, for it is on the far side, but I dare say that every member of the Society of Telegraph Engineers can imagine a counter for counting the time. The person in charge watches the counter, and for every 250 fathoms (that is, every 250 turns of the counter), he adds 3 lbs. to the break. That makes 12 lbs. added to the break, or to the resistance, for every 1,000 fathoms. The weight of 1,000 fathoms of the wire in the air is 14½ lbs. In water, therefore, the weight is about 12 lbs.; so that if the weight is added at the rate I have indicated, the rule stated will be followed. That is to say, you commence with a certain weight, and you keep adding to it as the wire goes out. Well, when the weight suddenly reaches the bottom, instead of there being a pull, or a moving force, of 24 lbs. on the wire tending to draw it through the water, there will suddenly come to be a resistance of 10 lbs. against its motion. A few turns of the wheel, two or three at

the most, suffice, and the motion is stopped; and, therefore, long before the clamp gets to the bottom, if we have 10 fathoms of line between the weight and the clamp, the wheel stops. The instantaneous perception of the bottom, when this rule is followed, is very remarkable. In the American process they describe the result as being most satisfactory. In their case, the wheel simply stops when the weight comes to the bottom; and they will detach, as I have said, and begin the hauling in direct on the wheel. My process differs from the American process in the mode of hauling in the wire again. [Sir W. Thomson demonstrated the method of hauling in by means of his wire-sounding apparatus.] We suppose the bottom to have been reached. In a moment the wire wheel is run back, and the wire gets upon the pulley. Observe, it has been paid straight down into the sea. We have a spun yarn stopper, which is put on in the usual way. In fact, two men with thick leather gloves can stop the wire by their hands, but the stopper is so quickly put on that I prefer it. The wire is then held by the stopper, the strain is taken off, and the weight is held by the wire. We then just cary the wire over the top of this wheel. If the depth be anything under 3,000 fathoms, I should say one line round is quite enough. For 4,000 fathoms I would take it twice over the wheel. It will work well enough when taken over twice, but a little more care is necessary. The stopper is now ready to go, and we haul in. The hauling in is conducted on just the ordinary sailor's plan, and the slack is taken off round a drum. By this process we can, by a few turns, relieve nine-tenths of the weight as it is coiled on the wheel. With one turn we can very readily take off three-quarters of the stress. I need not go more into detail as to process for accelerating the matter. I may just say that there are plenty of men available. Instead of handles I put on a pulley with a sharp V groove, one on each side; and then, with a snatch block, and with a deck 10 fathoms in board, the wire can be hauled tight; and three men hauling on one side, and three on the other, can get this up at a very rapid rate. By multiplying the speed in that way, there is no difficulty in hauling in at the rate of about 8 nautical miles an hour, so that the hauling in from a depth of 3,000 fathoms will be done in about 25 minutes at the utmost when proper arrangements are made. Of course, if there is a very heavy sea, augmenting considerably the stress above the mean stress, then slower hauling in will be practised. A little arrangement will be made by which the men can haul in as fast as they please, and be unable to put on more than a certain force. There will be the benefit of speed. It will come in fast when the strain is easy, and not come in at all when the ship is riding and would break the wire. That arrangement is exceedingly easy when we use the handles in the way that I suggest. The advantages of this process, I think, are very obvious. You see the simplicity of the apparatus, and the comparative inexpensiveness of it. No donkey-engine; no three or four hundred pounds of iron cast away every time, and so on, as in the ordinary soundings; and withal there is a very much surer sounding than the ordinary process can give at the same depths. And, lastly, there is the possibility of effecting a sounding in cases in which, as in the case of the Challenger in the Gulf Stream, the most mature previous process fails altogether. I think it highly desirable that this process should be taken up by our own Admiralty. There is a great tendency to the other side. I have a semi-official letter to the effect—"When you have your apparatus perfected, we may be ready to try it." I may say that it seems a little strange that after my having intimated, in the month of June, 1871, the perfect success of wire for sounding in depths of 2,700 fathoms, the Challenger was allowed to go to sea without taking advantage of this process, and that a year and a half later I should be told—"When you have perfected your instrument, we will give it a trial." The American navy looked upon the matter with different eyes, and certainly in a different spirit. They moved those who had the direction, and they took it up with the very greatest zeal. They found my apparatus full of defects, but they never asked me to perfect it, but they perfected it in their own way, and obtained results. I went on independently in another line, and made a considerably different apparatus from that which is now being used by the Americans; but I certainly was very much struck by the great zeal and the great ability which the American naval officers showed in taking up a thing of this description, which had once been proved to be good, and charging themselves with im-

proving the details, and making it a workable process. If I may be allowed two or three minutes longer, I will describe the method of making flying soundings with wire. In the first Hooper expedition, from Pernambuco to Para, the Brazilian Government sent a gunboat with us to take soundings, but the coal would not carry her the whole way, and we were left to our own resources for soundings during the laying of the cable. The whole route had been sounded over previously by the Brazilian Telegraph Company, so as to form a general idea of the line to be taken by the cable; but still it was very important that soundings should be taken accurately. Accordingly, Captain Headingley arranged that the wire wheel should be set up over the stern of the Hooper, and soundings were taken every two hours without stopping the ship. A 30 lb. weight was hung on a couple of fathoms of cord; but a greater length would have been better. I believe that 5 fathoms ought to have been used. Then the wheel was simply let go, with a resistance of about 8 lbs., or, perhaps, an actual resistance of not more than 6 lbs. on the circumference of the wheel. When the ship was running at the rate of 4½ knots an hour, the cable was paying out at the rate of 6 knots; and after, perhaps, 150 fathoms had run out—in some cases 175 fathoms—suddenly the wheel would get so much slower that it almost stopped. In half a turn it was obvious that there was a difference. The moment that difference was perceived, the man standing by laid hold of the rim of the wheel and stopped it. Thus they achieved flying soundings in depths of 150 fathoms with the ship going at the rate of 6 miles; and they obtained information of the greatest possible value with reference to the depth of the water and the course to be followed by the cable. I think this is of such great importance, that I never would like to go to lay a cable without an apparatus for flying soundings to be regularly practised, say every two hours at the least. The warning that this practice gives of shallow water, or of too great a depth of water, has a value which, I think, the members of the Society of Telegraph Engineers will readily appreciate. There is one point which I omitted to refer to, and that is the arrangement of the stern pulley. It is arranged so that if the ship is making a good deal of lee way, the wire may still be hauled in. Supposing the ship is drifting, and making lee way, instead of being at right angles, we can haul just as well. The wheel turns on a horizontal axis, and there is no strain on the wire at all. A very moderate amount of drifting, especially in a sailing vessel, may produce a great alteration in the angle, but it makes no difference to the hauling of the wire. The wheel turns readily round either way, and even during the rolling of the ship you can keep the wire on the wheel. I tested it with a wire like this on the steam launch Hooper, and the wheel accommodated it to every quick movement of the vessel. There is one interesting topic in connection with this plan of using wire, and that is the sound produced by the wire. All the time we are employing piano-forte wire in this way, we have a "sounding" in a double sense. There is always a vibration going on, and there is this use which we may make of the sounding quality of the wire. By putting a stop in a given position on the wire, we can estimate the strain on the wire with great accuracy. If you stand by the wire and give it a little blow, a good musical ear can tell within 10 lbs. what the strain is, simply by the sound.

Mr. Froude said that he had the pleasure of seeing the first specimen of sounding wire which Sir William Thomson had made, before it was used. He forgot whether at that time Sir William Thomson had hit upon his extremely ingenious and nice mode of taking the strain off the wheel; but one could see at once that it was perfectly easy and must succeed. The idea of making a strong joining in the wire by a long succession of weak fastenings, seemed a very instructive mode of getting over a serious difficulty. He saw from the beginning that the joints might be put together by solder; but it was obvious to him that the stiffening of the wire by the solder must have a bad effect. He thought that it was much to be regretted that the Admiralty did not at once take up Sir William Thomson's process. They were much more disposed to take up such things than they used to be; and he was rather surprised, knowing how high Sir William Thomson's authority stood, that they should have any hesitation in taking up the process. He (Mr. Froude) wished to ask how the difficulty of corrosion by salt water was ultimately overcome. The use of oil had been under discussion.

Sir William Thomson said that there

were two methods of guarding against rust. The Americans used oil by submerging the wheel in oil when it was out of use. Commander Becknack having carried out the process of wire sounding with remarkable success, he (Sir William) supposed that the Americans were satisfied with the preserving power of the oil thus used. On board the Hooper the deep sea sounding wire was preserved by caustic soda when out of use. That substance, when bought wholesale, was so inexpensive that the cost of that mode of keeping the wire from corrosion was not worth speaking of. There was, however, a good deal of trouble connected with it; but it must be remembered that that trouble would not be regarded on board a ship appointed specially for making soundings. The preserving effect of alkali upon steel was well known to chemists. It seemed to be due to the alkali utilizing the carbonic acid in water, for the presence of carbonic acid in water was the great cause of iron being corroded. The fact was well established that iron would remain perfectly bright in sea-water rendered alkaline by a little quick-lime. Caustic soda was a more sure material, because we could make more certain that the water was really alkaline. He was told by a very excellent authority, Mr. James Young, the chemist, that whether caustic soda or quick-lime was used, all that was necessary in order to make sure that the pickle would be a thorough preserver of the wire was, that it should be found to be alkaline when tested with the ordinary litmus test-paper. The American experience was, that although the caustic soda preserved the wire, it ate away the solder, and on that account the Americans adopted the use of oil. Oil seemed objectionable on account of the mess and slipperiness which it would cause if it got scattered about the deck; and yet the Americans seemed to manage to work with it very well.

Mr. Matthew Gray said that sixteen months ago he had occasion to lay a cable across the Bay of Biscay, and previously to that time, though he had never heard of what Sir William Thomson had done, he got an apparatus made very much like the upper portion of that which was now exhibited. In going to sea with it, they found no difficulty in taking the soundings in 1,300 fathoms. He was not so fortunate as Sir William was, in getting good wire of sufficient strength to pull up the weight, and the wire was broken two or three times. At last they constructed a weight which got left at the bottom when it touched the bottom, and with that they were pretty successful. They used oil for keeping the wire from rusting. The oil was kept in a trough, and a flat india-rubber bearing, rubbed against the wire to rub off the superfluous oil, and keep it from flying over the deck. That seemed to answer the purpose very well. He might mention that he also made an apparatus with a view to picking up a larger portion of the bottom than is usually done. It was shaped something like a sugar-tongs, but the jaws were not fitted with sufficient accuracy, and the water washed out the material which the tongs took up. He had no doubt that in all cable-laying in the future, much would be done by the apparatus which Sir William Thomson had constructed.

Captain Hull said that in his surveying experience he had had very little to do with deep sea soundings, but, in consequence of what he had heard that night, if he was sent to perform deep soundings, he should apply for his ship to be fitted with such an apparatus as Sir William Thomson had described. He (Captain Hull) thought that some modification might be made in the mode of taking flying soundings by the use of an old-fashioned implement used by sailors. It was a kind of floating pulley connected with a little canvas bag, which would indicate when the bottom was reached by acting in the reverse way to a float such as is used in ordinary fishing.

Mr. Matthew Gray said that he should like to know how it was that Sir William Thomson's pulley was so much injured by the weight of the wire, and why it would not do for the wire to drop up direct from the pulley. He (Mr. Gray) did not find any difficulty arising from that cause. Perhaps Sir William Thomson would say whether he brought up anything from the bottom, and if so, how he did it.

Mr. Latimer Clark asked how the friction strain on the wheel was regulated and adjusted, and also whether the sinker was recovered in flying soundings.

Professor Clerk Maxwell asked whether cross-filing of the wires at a splice for increasing the grip would do so much harm by weakening the wires as to outbalance the advantage of the increased hold.

Sir William Thomson, in reply, said that cross-filing to prevent slipping would in-

jure a wire by taking away its strength, more than it would help in increasing the friction. Marine glue was found to answer so well that he did not think that any process of roughening was necessary. For regulating the resistance, he used a form of brake which he patented in the year 1858, and he had used it in his own laboratory ever since, though it had not come into general use. It had answered very well, and he believed that it might be used with advantage in paying out a cable, although there were difficulties in the case of a cable which could not be rashly dealt with. Besides the groove which carried the wire, there was a groove with a semi-circular section, into which the rope was placed one turn and a quarter round the wheel. The end of the rope was secured to a pivot. [The use of the brake was demonstrated.] The question of regulating the resistance might be answered in this way. The difference of tension of the cord at the heavy tension end, where the weights were attached, and the light tension end, was equal to the resistance. He had used a spring balance at one end. The method was to note what a spring balance was standing at, and then subtract it from the weight. That would show what force was on. He had another appliance. It consisted of simply casting off the cord and putting on a hook over the rim of the wheel. This was carried over the pulleys, and with a cleet was hauled off on a spring balance. The spring balance would weigh with the greatest accuracy the stress upon the wire. With regard to Captain Hull's suggestion as to the use of the canvas float in flying soundings, no doubt it would increase the accuracy of the sounding, but it would induce some degree of complexity, which must be avoided. As to the recovery of the weight, he might say that they always accomplished it, and they never lost a pound of lead if they could help it. His process was in this respect a great contrast to the ordinary method. Six men would be required to bring up the ordinary heavy sinker. There was also a great saving of time as compared with the ordinary method. At 2,000 fathoms, the wire would take not more than ten minutes to run down. A 30 lb. sinker might be hauled after a depth of two miles in fifteen minutes. In fact, twenty minutes could be made sufficient for a 2,500 fathom sounding when the object was to perform the sounding in the shortest possible time. The flying soundings of which he had spoken were only approximately correct; but they were useful as guides in the laying of a cable, and a little experience would enable the observer to make such an allowance as would give the accurate depth. Mr. Gray had put a question about specimens of the bottom. He (Sir William Thomson) had obtained specimens of the bottom by means of a butterfly valve of the ordinary pattern. Mr. White had made an improvement on the butterfly valve, and many other improvements had been made upon it.

The Chairman expressed the thanks of the Society to Sir William Thomson for his interesting communication. Like most other mechanical arrangements, the method which had been described was not absolutely new, and he (the Chairman) was not surprised to hear that attempts had been made to sound by means of wire instead of line; but the merit of the present apparatus, as well as of any other well-advised mechanical arrangement, consisted of the appliances to make the result a perfect one, and in that respect the apparatus would commend itself without any words from him.

There were many difficulties which presented themselves at first sight against the use of wire for soundings, but they were met in the most perfect and ingenious manner. First of all, to get wire of such uniform strength as to reach to a depth of three miles required very considerable attention. Nevertheless, piano-forte wire offered extraordinary strength and a certain degree of toughness, and was, therefore, a very inviting material; but how to join the wires in such a manner as to be thoroughly reliable was a matter requiring very mature consideration, and this difficulty had been met in the most perfect manner. Then the mode of checking the motion of the drum by a single rope, though in itself involving only a pony brake, was a very ingenious adaptation of means to the particular end, and it was brought in usefully for telling in the most absolute manner when the weight struck the bottom. There were other points of great ingenuity about the machine, and he had not the least doubt with regard to its practical value in making deep-sea soundings by wire. He had himself made deep-sea soundings some years ago, and he knew that for a depth of 2,000 or 2,400 fathoms they always took up the best part of the day, or at least some four or five

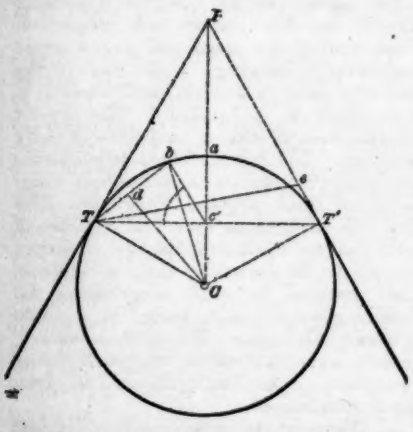
hours, and it was a very difficult matter sometimes to keep the stern of the ship over the line. The latter friction of the line in the water was so great that the load would not follow, and therefore the ship had to be manœuvred so as to keep over the line. The wire apparatus, instead of occupying five hours, accomplished a complete deep-sea sounding in thirty-five minutes. That was a matter of really the highest importance, especially in making the soundings for a submarine line, where time was sometimes a very great object. The flying soundings were also matters of great interest. If they could be accomplished with any degree of certainty with this apparatus, it would be a great achievement. For his own part, he had sent out the apparatus with every ship which he had lately had to fit for sea.

LAYING OUT CURVES OF SMALL RADIUS.

By G. H. MANN, C. E.

Written for Van Nostrand's Magazine.

The method of laying out railroad curves by deflection is often inconvenient, when the radius is small, as the chords must be taken very short and are frequently inconveniently close to the instrument; the method by perpendiculars to the chords requires too much changing of the instrument, and is deficient in economy of time. The



writer has employed the following method to advantage, when the point of intersection was not accessible and the radius small.

The random line T e is first run, and the angle I found by measuring I e T and I T e, and taking their sum from 180°. Then I T T' determined, and the chord T T' located. On this middle point, c' is taken as the station. Then, if we lay off any line c' b, making an angle I with the chord, the distance on this line to the circle will be

$$d = b\,c' = \sqrt{R^2 - h^2\cos^2 I} - h\sin I. \qquad (1.)$$

R = radius of circle $= \frac{\frac{1}{4}\text{ chord}}{\sin \text{I T T'}}$, or $\frac{\text{T } c'}{2\sin \text{I T T'}}$;

$h = c'\,\text{C} = \frac{1}{4}$ chord $\times \tan \text{I T T'}$;
or T $c' \times \tan$ I T T'.

This value (1) may be determined as follows:

$$x^2 + y^2 = R^2. \quad . \quad . \quad . \quad (2.)$$
$$x = d\cos I,\ y = d\sin I + h.$$

(2) becomes

$$d^2\cos^2 I + d^2\sin^2 I + h^2 + 2\,d\,h\sin I = R^2.$$
$$d^2 + 2\,d\,h\sin I = R^2 - h^2.$$
$$d + h\sin I = \sqrt{R^2 - h^2 + h^2\sin^2 I}.$$
$$d = \sqrt{R^2 - h^2\cos^2 I} - h\sin I.$$

Or we may, if stakes are to be set at equal distances along the curve, proceed as follows:

Let T b = V $\sphericalangle$ T c b = α, b T c' = β.

Then $\alpha^\circ = \frac{l}{2\,\pi R} \times 360°$, and

$\frac{1}{2}\,\alpha^\circ = \sphericalangle$ T c d or b T I $= \frac{l}{\pi R} \times 90° =$

$\frac{l}{R} \times 28° 39'$; then

$$\beta = \text{I T T'} - \tfrac{1}{2}\alpha.\ d^2 = \overline{\text{T}c'}^2 + \overline{\text{T}b}^2 - 2\,\text{T}c\,\text{T}b\cos\beta,$$

or if c = chord, $d = \sqrt{\frac{1}{4}c^2 + l^2 - c\,b\cos\beta}$:

and angle I is found thus:

$$\sin I = \frac{l\sin\beta}{d}.$$

It will be noticed that the exact length of each arc is laid out, and no error arises from the chord being taken equal to the arc. For curves of small radius, and where the length of arc is required to be quite small, this method has the advantage that the instrumental work can be done very rapidly.

IRON AND STEEL.

From the "London Mining Journal."

The only sure and certain path to perfection in any branch of manufacture is undoubtedly that of painstaking research and analysis. By this means the basis and principle of any successful operation is distinctly pointed out and noted, and the causes of failure observed for future avoidance. Thus every failure and every success alike become steps to increased knowledge and better success for the future. If there is any one branch of manufacture that we pride ourselves upon, it is surely that of the working and production of marketable iron and steel.

We should not, however, from our practical successes conclude that we have nothing further to learn in this branch of manufacture. And we should further give careful heed to the results which any painstaking investigator or analyst may publish to the world, since we can never say but that some as yet undeveloped germ of truth may therein lie hid ready to the hands of the enterprising practical man for production as a great commercial success. With these few words of preface we feel sure that our readers will give careful heed to the results of some most painstaking and exhaustive investigations in iron ores and steel by an eminent French metallurgist and chemist, M. Fremy.

He states in order the important facts at which he has arrived, some of which we think will be rather subversive of the established ideas and prejudices of the iron and steel producers at large.

1. He declares that there are no ores distinctly differing from iron ores as suitable for the production of steel. All good iron ores will produce good steel if they do not contain any minerals unsuitable to the production of steel.

2. The steely character of some ores is due simply to the purity of the iron, and not to any peculiar property of any special ore. In fact, the suitability of an ore to the production of steel depends on good metallurgical work rather than on any special quality of the ore.

3. Carbon is undoubtedly the essential element in producing good steel and good castings from ore. But it is not the only body which may be in true chemical alliance with the iron, as for instance the silicium in the Bessemer castings, or the manganese in spiegeleisen.

4. The bodies which will combine with iron are numerous, and they will by their combination produce an infinite variety of results.

5. The irons of commerce, the steels and the various pigs, should then be considered as alloys of iron, in which varying quantities, often of minute amount, of different compounds, primarily carbon, then sulphur, phosphorus, and arsenic, produce definite qualities of material.

6. It is a well-known fact, that commercial iron is far from pure iron, or even from a simple compound of iron and carbon. The qualities of the various brands are modified by sometimes extremely minute quantities of foreign substances. The various brands and varieties of iron should be considered as the most important alloys that iron can form with other elements. These agents modify the iron depending directly on their nature and proportion. Some harden the metal and give it great resistance to shearing; while others, on the contrary, raise its tenacity, and cause it to lose others of its qualities. The present classification of iron is undoubtedly sadly deficient. The best and most precise terms are simply founded on an incomplete recognition of their physical characters. The day will surely come when all varieties of iron shall, as in other mercantile substances and alloys, be known by chemical analysis, and produced as exact compositions, the definite physical nature being an absolute necessity thereupon. This plan has already been to some little extent adopted in one or two places on the Continent, and has given great satisfaction.

7. There are two great heads or divisions in what we term wrought iron. These are fibrous iron and crystalline iron. The crystalline iron is usually the result of the combination of a minute quantity of carbon with the iron. This may be considered to be always the case where the crystallization is natural and stable. An abnormal crystallization is, however, often produced by sudden chilling, or, it is said, by continued hammering; but this abnormal crystallization can be always removed by annealing.

8. The third modification of iron with alloys, but principally with carbon, is that of the family of mild steels. It is difficult to draw a line between crystalline iron and mild steel; however, the grain of mild steel is brilliant, generally very fine, and cannot very well, when compared, be confounded with that of crystalline iron. Soft steels should be considered as alloys of iron and carbon only, with an exception in favor of manganese. All other substances spoil its quality.

9. The fourth modification of iron comprises the numerous families of brittle and hard steels. These steels are produced by the combination of iron with a considerable portion of carbon, and also by the combination of other bodies, of which the hardening effect is added to that of carbon. It should be particularly noted in the manufacture of steel that if the presence of some bodies are beneficial to the combination of carbon and iron to produce steel, there are other very injurious substances, such as sulphur and phosphorus, which act as deterrents, preventing the easy combination of carbon and iron. These should be removed with as much care as an acid or alkali preventing a wished-for precipitate would be from a chemical solution.

10. The fifth modification produced by the combination of a still greater excess of carbon, both chemically and mechanically mixed, and also with other various bodies, is the variety of cast irons, varying through soft, hard, tough, brittle, grey, or white. Although this form of iron is usually the first obtained from the ore, it holds, as a chemical alloy, a position further removed from pure iron than steel. It was the full appreciation of the chemical order of cast iron, steel, and then wrought iron, that originated the Bessemer simplicity of production of steel from cast iron, instead of from the purer wrought iron.

All the foregoing facts may be, and probably are, well known to any who may have made iron and steel their business or study; but we think that the possibility of accurate chemical classification of all varieties of commercial iron, is an idea as yet not generally received or understood. We firmly believe that such a classification will be a fact in the near future, and that the uniformity of various classes and brands of iron will be thus greatly enhanced.

ILLUMINATING BY THE MAGNETO-ELECTRIC LIGHT.

From "The English Mechanic and World of Science."

In our last volume it was stated that a Mr. Ladiguin, of St. Petersburg, had succeeded in removing some of the defects connected with the utilization of the magneto-electric light for purposes of illumination. Some experiments with this method were carried out recently at the works of Messrs. Warner, in the Euston road, in the presence of Sir C. Wheatstone, Mr. Sabine, Col. Stuart Wortley, and many other scientific men. M. Lodyghin (as it appears his name is spelt) has invented a system by which an electric current can be subdivided and so made to produce a number of lights. The subdivision of the electric current as it flows from the generator has before been attempted, but the fine carbon points were quickly consumed when burnt in contact with oxygen. Thin platinum wires have also been tried, but as soon as they commenced to give a perfect light they were melted. It occurred to M. Lodyghin that the difficulty might be overcome by using a vacuum, and so burning the carbon out of contact with the oxygen of the atmosphere. Metallic connections, however, had to be used, and as the metal and the carbon expanded in different ratios, the carbon was subject to fracture. The metal, moreover, melted at the points of contact with the carbon, and so the question remained practically unsolved. M. Lodyghin's idea was then taken up by M. S. A. Kosloff, who, after many months of experimental research last year in Paris, at length succeeded in overcoming all difficulties, and in producing a practical and efficient means of subdividing the electric light. M. Kosloff has invented a special metallic alloy of which he forms the holders for the carbon points (or rods, as they are more properly termed), and these are placed in a glass vacuum chamber or lamp. The lamps which were experimented with were nine in number, six of them having two carbon rods, either of which could be placed in connection with

the current of electricity. The rods were all 18 millimetres in length, and one in each lamp was 2 millimetres in thickness, the others being 1¾ millimetres thick. The other three lamps contained each a carbon rod 70 millimetres in length, 2 millimetres thick, and also connected with the main current.

The first experiment consisted in burning a carbon rod in contact with the atmosphere, the rod being consumed in a few minutes. The current was then turned on to the thicker rod in each of the six lamps, and a brilliant but not overpowering light was produced, which improved as the current was increased in intensity. The reason for lighting the thicker rod first was that it might consume the oxygen in the lamp, by which the rod was reduced a quarter of a millimetre, and was thus brought down to the gauge of the second rod. The current was then directed through the second rod with equally satisfactory results in all the six lamps. The three lamps with the longer carbon rods were then lighted and successfully exhibited, changes being frequently made from the six to the three lamps and back again. The apparatus used for producing the current was Gramme's magneto-electric machine, which was illustrated and described on p. 557, Vol. XIII., and which produces a fine continuous light. With the Gramme machine running at about 200 revolutions per minute a moderate light was obtained, which was greatly improved at 300 revolutions, the maximum of intensity being obtained at 450 revolutions. The strength of the light depends upon three things—the power of the machine and the number of its revolutions, on the length and thickness of the carbon rods, and on the quality of the carbon. The experiments showed that with the same strength of current and the same number of revolutions, double the amount of light was obtained with the three long carbon rods as compared with the six short ones.

The experiments demonstrated satisfactorily the fact that the electric current could be subdivided, and hence, if practice confirms experiment—which it is believed it will—there is a wide field open for the application of Kosloff's system. And it should be here remarked that the form of lamp used by the inventor is also experimental, and its variation does not affect the principle. He leaves it to mechanical science to devise a lamp which shall meet the varied requirements of lighthouses, mines, submarine works, railways, and other purposes, to which, it was the general opinion of those present at the experimental trial, the principle is thoroughly applicable.

THE NEXT LARGEST STEAMER AFLOAT.—On the 6th ult. Messrs. J. Elder & Co., of Glasgow launched a vessel for the Pacific Steam Navigation Company. She is 460 ft. long by 45 ft. wide, and 37 ft. 6 in. deep, and is of 4,820 tons, gross. This makes the sixth vessel which this firm, which is the leading one on the Clyde, have launched for the same company. The steamer is to be fitted with compound engines of 650 horse power nominal, will be bark-rigged, and will have iron masts; and for the convenience of loading and discharging cargo, 5 powerful steam winches have been fitted up. She has capacity for 4,500 tons measurement, exclusive of 900 tons of coal. The ship is divided into 8 water-tight compartments, and has 8 small boats, one of which is a steam launch. She will have accomodation for 140 first-class, 50 second-class, and 800 third-class passengers. The saloon will be 41 ft. by 40 ft. wide, giving accommodation for 140 passengers dining together. The officers and crew will number 120. This vessel, which is the largest merchant ship afloat, with the exception of the Great Eastern, was built in the short space of nine months, and the firm have a sister ship on the stocks for the same company. When the ship left the ways she was named the Iberia.

SAFETY-LAMPS.—Mr. J. B. Stone, of Birmingham, has patented an invention which consists in improving the illuminating power of the said lamps by making the glass surrounding the flame of a cylindrical figure within and a convex figure without, or convex both within and without. By this means the light is so concentrated that when the lamp is hung vertically the illumination is for the most part directed horizontally at or about the level of the lamp. When the light is required to be directed upwards or downwards the glass is made of a conical figure.

THE STEAM ENGINE OF 1833 AND 1873.*

From the "English Mechanic and World of Science."

The period selected (forty years) is about identical with my own experience on the subject; and my object this evening will be to draw your attention to some of the main differences of practice in the two periods. In the neighborhood of Manchester, in the earlier period, the boiler pressure would be from 7 to 10 lbs. per sq. in. above the atmosphere; and the present pressure may be taken at about 70 lbs., which is about eight times greater now in excess above the atmosphere than at our first date. The engines mostly in use, and in course of construction, at the former period, for driving our cotton and woollen mills, were the stationary beam-engine, and the side lever or marine-engine; many being Watt's and Murray's make, and other copies of their productions.

The steam generator, or boiler, is so intimately connected with the steam-engine that I cannot draw your attention to the latter without making a slight reference to the former. I may just state, therefore, that the boilers mostly in use were the wagon or haystack, and the butterfly or fish mouth; also the cylindrical dish-ended, without flue; and the cylindrical flat-ended, with one flue, fired in the flue; the two latter kinds being mostly used for non-condensing engines. About 1840, or say seven years after our first date, considerable efforts were made to economize fuel, which resulted in the more general use of stronger steam, and a corresponding increase in its expansible force; perhaps thus following in the wake of the Cornish engineers, who had about this time successfully attained very high results in their application of these principles to the pumping-engines of that district. It was about this time that the double-flued, internally-fired boiler, began to be introduced in this neighborhood; and also various modifications of that form of boiler, all with a view to meet the demand for greater production, economy of working, and lessening the nuisance from dense smoke. On the passing of the Factories or Ten Hours Act, these demands were much stimulated, as it practically necessitated the production of twelve hours' work in ten hours, by the same engines and the old number of boilers. The impetus thus given to the economical driving of our mills and works has continued up to the present time, and is at this moment of perhaps greater importance than at any former period, owing to the very largely increased cost of fuel compared with its former value.

The improvement made in the steam-engine itself during the periods we have named, does not consist in the invention of any entirely new model or class of engine, but rather of an elaboration and rectification of designs previously suggested or used; and in the selection of the simplest forms applicable to the various purposes and situations for which it is required. Notably, the horizontal form is one which is very generally applicable. It is not liable to the defects which were prognosticated, and which appeared inherent on its first introduction, namely, the rapid destruction of the cylinder and piston by the friction of their bottom surfaces by gravity; such tendency being almost wholly counteracted by other forces, as has been abundantly proved by very large experience. The vertical direct-action engine, overhead or inverted, has not proved itself so generally applicable as the horizontal, especially in the larger structures, partly from the difficulty in getting sufficient stability, partly the want of balance, and partly the inconvenience of getting to the various parts. The direct-action forms have, however, largely supplanted the stationary beam and side lever kinds, and would have done so more rapidly and effectually if the designers had not usually mutilated the proved effective proportions generally used in the older kinds, by cramping the new designs into very much too small a space to obtain their maximum effects. Indeed, the proportions used by the celebrated Watt, and other old engineers, have been proved so thoroughly beneficial and mechanically correct, that a strong prejudice exists in favor of long-stroke engines; and I beg to suggest that that is mainly because the old makers used such good proportions in the conversion of rectilinear into circular or rotary motion,—that is, the length of the connecting-rod relative to that of the crank or other medium of communication. The result of my own

* Read before the Manchester Association of Employers, Foremen, and Draughtsmen, by Mr. G. Saxon.

observation and experience is, that very much too little attention has been paid to these proportions; and I am not, therefore, surprised when our modern engineering, in such cases, compares unfavorably with the past.

Various examples might be adduced in confirmation of this experience, but I will simply name one, which is that of a firm of the most celebrated stationary engine makers in this locality—perhaps in the world—being engaged to supply a pair of vertical direct-action engines to compound with a pair of beam-engines of their own make, so as to economize fuel.

As I happened to be consulted about the same work previous to the contract being placed, and also engaged on other work for the same firm at the time, my attention was drawn to the extreme shortness of the connecting-rods in this case. I explained my views to the proprietor, who was so far convinced that he immediately communicated with the contractors, with a view of having the requisite alterations made, and the averred defects remedied. The response, however was that similar proportions were used in Her Majesty's Navy, and a desire to proceed with the original design, which was consented to. But mark the result! On the first day of starting these engines the slides on the bearing side ploughed fire, broke the crosshead and slide off one engine, and brought the machine to grief immediately. The disaster was remedied by trebling the strength of the slide, and doubling the rubbing surface of the slide block, and this arrangement continues to this day. It is not, therefore, surprising to find the result unsatisfactory.

As a contrast, amongst others I will quote the case of a small vertical direct-action overhead engine, which chanced to be on sale, with urgent delivery, to clear off, when I was just about commencing business at our present works. This engine had the very unusual property of more than the old standard proportion of connecting rod to crank (being eight to one). At the time I was perfectly satisfied with the price, and have since been with its performance; and if merit is to be the rule of promotion, I should place it in the van of the small fry. Like other engines, certain parts will necessarily decay, and require removal, but those parts which are usually affected by unnecessary friction are very long-lived in this one; and rude and small as the model may be, a most useful lesson may be drawn from its performance. It is still doing good work, and will probably long continue to do so.

Whilst on this part of the subject, I may mention that over twenty years ago, whilst engaged as chief engineer at a large engine works, I induced the proprietor to lengthen the whole list of horizontal patterns, and obtained highly beneficial effects. At the present time I am building a pair of horizontal engines with a proportion of seven and a half to one, which are designed to run at a moderately high speed of piston—576 ft. per minute.

During the period before specified, the oscillating cylinder engine, and the truck engine, have both—but especially the former—been largely used in special situations; notably for marine purposes, where economy of space is the first consideration. Their application for mill purposes, however, has been very limited; and it appears to me they will be still more restricted in cases where space is only a matter of secondary importance.

The double-cylinder engine of Wolff, now commonly called the compound engine, was hardly known at our earliest date, but it has gradually forced itself into use, until at the present time it has become almost as common for large structures as the single-cylinder engine, in consequence of its better adaptability for high pressures. Some engineers of note have disputed this, and maintain that the single-cylinder engine can be used with quite as great economy, and with a simpler machine. The results obtained by the Cornish pumping engines no doubt go to support this view, but the practical application of strong steam to rotative engines seems to demand its first introduction on the reduced surface of a comparatively small piston, acting through a considerable portion of the stroke, and to be afterwards expanded in a larger cylinder, whose capacity is several times that of the first one. Such engines I have found to give great satisfaction, both in comparatively large and small structures; and to work with a very high degree of economy, whilst the wear and tear is by no means excessive.

The practicability of using these compound engines is no doubt due to the great improvements which have been made of late years in the manufacture of boilers. Firstly, in having a better material readily

obtainable; and secondly, in a number of slight improvements of detail in construction, which, taken altogether, enable us to construct a good, sound, reliable vessel, up to 100 lbs. per sq. in., on the Cornish-flued, internally-fired principle, and to still greater pressures on the French, and small pipe systems. One great improvement in the internally-fired boilers has been the introduction of pipes in the flues, which, whilst they strengthen the flue, also increase the heating surface, and very greatly promote the circulation of the water, which is of the highest importance.

About twenty years ago a number of cases came to my knowledge where the flues had no pipes in them, and the feed water was passed through the mud hole at the bottom without being heated higher than the temperature of the hot well. The result was most destructive. The expansion of the boiler was most irregular, and caused the plates in the bottom of the shells to rip off alarmingly frequent. The remedy is to heat the feed water, and introduce it near the upper surface of the water in the boiler when working, and to apply pipes in the flues to obtain circulation.

While speaking of boilers, I may just remark, that two or three years ago, having taken a contract to supply a pair of compound engines, and my customer having determined on giving the order for the boilers to a firm who make it their especial business, he introduced me to the senior partner, in order that I might explain to him what kind of boilers it was desirable he should have. I insisted they must be plain, practical, simple boilers; and to carry a working pressure of 100 lbs. to the sq. in. The greatness of the pressure caused him to shake his head, and ultimately he took a week to consider of it, at the end of which time we again met; he smiled, and produced his specification, which was accepted. Since that time the same firm has made a number of similar boilers, and I believe they are quite as safe as those which they formerly made to carry a much lower pressure.

About the time of our earliest period, the Spur Fly Wheel, with the teeth on the outer circumference, was being introduced, as a substitute for the second motion fly-wheel, which had previously been generally applied. Owing to the slowness in the working of the earlier engines, the requisite uniformity of turning was best and most satisfactorily obtained by placing the fly-wheel on the second motion shaft, which revolved much faster, and the desired effect was obtained by the least quantity of material. This arrangement had, however, the defect of causing a backlash in the gear connecting the crank shaft with the second one, which, in some cases, proved an annoyance. The application of the spur fly, which has the merit of great neatness, enabled the engineer to get up the speed of the shafting rapidly; and many cases have occurred where this has been done to excess, such as a large wheel working into a relatively small pinion, causing a great loss by friction.

The improvements in the mode of moulding toothed wheels, and their greater accuracy, has enabled them to be run at a quicker speed than formerly; and the greatest advantage possible has been taken of this improvement, to obtain the highest speed of piston practicable. Some engineers, however, myself included, do not use the spur fly, but a wheel of less diameter, either bolted to the arms or otherwise, which arrangement allows a much greater velocity of crank shaft and consequent speed of piston, whilst the wheel teeth are run at a safe practical speed, and at such a velocity as to obtain the necessary momentum with the least weight of material, which is very important, in order to keep the bearings cool and to reduce the friction.

In the earlier engines the pistons were packed, so as to prevent the passage of steam, by the insertion of a hempen gasket, which was compressed by a junk-ring or follower-plate, secured by the requisite bolts. It soon, however, became a desideratum to find a metallic substitute for the gasket. Various plans were proposed, and some were in operation at our early date; but about 1848 a great impetus was given by new inventions for this purpose, and the construction of machinery for reboring the cylinders of existing engines in their places, without removal. The importance of having a cylinder truly bored, and fitted with a good self-adjusting metallic packed piston, so constructed as to work with a minimum of friction, and yet not permit the escape of steam, can hardly be overestimated. Indeed, it is hardly possible to conceive the cost of material, labor, and serious loss by stoppages which were involved by using the gasket packed

piston; and these defects were largely increased as the pressure of steam was raised. My own experience and recollection of it, in one case, are simply appalling. Morning, noon, and night, the cover had to be raised, the follower tightened, or a new layer of gasket inserted; while it was quite an ordinary thing to come to a dead stand during the working hours, send for a batch of men, who would pull the covers off, examine every working part, and get to work again as soon as practicable. I must observe that, as the pressure of the steam in the boiler in the case alluded to was so extremely low, a tolerable vacuum was indispensable. A few years after my first introduction to the works, this engine, which was a side-lever one, made by Boulton and Watt, had its cylinder re-bored, a new metallic piston fitted, and supplied with stronger steam, when all difficulties immediately disappeared.

In most of the early engines the cylinders were steam-jacketed. Considerable difficulty was, however, experienced in keeping the joints steam-tight. From this cause mainly, they were gradually given up, and became almost extinct. They have, however, of late years been reintroduced, it is said, with advantage; but a great deal must always depend on the connections being kept quite distinct.

The working valves for regulating the admission and emission of the steam to and from the cylinders of steam-engines, and the various modes of operating them, have always held a high place in the estimation of the engineer. They are so multifarious in kind and character, that I cannot even attempt a general description of them at the present time, but shall just remark that the D valve of Murdoch is still largely used, and when made of good bell-metal, and properly packed with gasket, they are good up to say 30 lbs. pressure. The valve now most commonly used is the slide, with the steam pressing on the back, operated by rods moved by an eccentric. Other very beautiful arrangements of working and expansion valves have recently been explained to you, and will doubtless be fresh in your recollection. Whilst speaking of valves, it may be proper to remind you that apparatus has recently been devised for replaning the valve facings of side pipes, and other facings, in their places, without removal, and operates very satisfactorily.

The very great desirability of uniform speed of the steam-engine, whether lightly or heavily laden, had already received due attention; and during the period we have chosen, many highly ingenious devices have been suggested, with a view of obtaining the desired end more perfectly. The pendulous long-armed governor of Watt, acting upon a wing, or revolving vane throttle valve, answered tolerably well whilst the pressure and speed remained low, but as these became augmented a more sensitive regulator became desirable. In numerous instances this has been attained by running the pendulous governor somewhat above its normal or natural speed, and counterweighting it, so as to get the required speed of engine with a greatly increased sensitiveness, whilst the wing valve has been superseded by the equilibrium valve, which, when properly constructed and applied, is equally easy to move under any circumstances, such not being the case with the older valves, which required considerable force to reopen them when closed. The application of the "equilibrium throttle valve," I consider, is a great improvement of the modern engine; and the invention and attachment of the high speed governors, in several of their various forms, has resulted in our obtaining a very high degree of regularity in the working of steam-engines; although it must be admitted that the constant tendency to entirely shut off, and instantly reopen the steam communication, must be a severe trial of the strength of the various parts, and is especially undesirable in the larger engines. In consequence of this excessive action, I have generally been satisfied with the pendulous governor, with long arms, modified as just described, and acting upon a good equilibrium valve. This arrangement I find to give very regular turning, and is not nearly so liable to shocks as the very high-speed ones are.

At our early date the single-acting air-pump was almost universal, and the cover or top was placed immediately over the delivery passage of the water. This arrangement proved a great barrier to increasing the speed of engines, and it has been removed by elevating the cover a distance above the passage, so as to form an air receiver and cushion to ease the delivery of water. The double-acting air-pump has been frequently and beneficially employed, especially for high speeds. As a rule, the vacuum obtained is not so perfect as in the older arrangement, but its other advantages,

in certain cases, more than counterbalance the defects.

Condensers formerly were exclusively of the injection class, and for land engines generally remain much as they were, except that owing to the increased speed they also have had to be made larger. The surface condenser is of great value to the engineer. In many cases where it is undesirable that water used for condensation should be also used for the generation of steam—and which is generally the case with marine engines—very considerable ingenuity has been exercised; and in several instances satisfactorily, to get a good surface condenser.

The locomotive, portable, and road engines have received the careful attention of the engineer during the period embraced by our review, and this has resulted in an astounding development in their application. Like the stationary engine, however, the improvements have necessarily been of a detail character, as the main characteristics were settled at the opening of the old Liverpool line. Very great minor improvements have, however, been effected; as an instance of which I may name the link motion, which very beautiful arrangement permits a very rapid and safe reversal of the motion, and also at the same time gives us a means of varying the expansion of steam to suit the various requirements. The link motion is now generally employed where steam engines are required to revolve in alternate directions. The radius parallel motion of Watt for guiding the piston rod in its many varied forms is not so generally employed as formerly; but has been largely superseded by fixed guides or slides, which, being simpler, have been preferred in the various kinds of direct-action engines.

The improvements which have been made in the various tools and machines used by the engineer have enabled him to execute a much more durable and solid structure than formerly; and to dispense with some of the rude and costly modes of connection formerly used, as, for instance, rust joints, which are now almost obsolete. India-rubber has been of especial service both in the form of washers and valves.

Steam hammers, which have been almost wholly invented and brought into very general use since our early date, demand at least a passing notice, if only on account of their enormous importance at the present time. They have almost revolutionized some branches of business to which they have been applied, but they are sufficiently important to demand a special notice or paper, and so we will leave them.

THE POLLUTION OF WATER.

From "Engineering."

In "Notes on Sewage," which will be found in a series of articles in the two preceding volumes of "Engineering," numerous, chemical difficulties have been mentioned in regard to what is called "sewage contamination." The determination of this in various specimens of sewage, in ordinary water supply, in wells, etc., is yet far from satisfactory. The most eminent chemical authorities differ not only in respect to the results they obtain, but also in the methods they employ for its determination. The matter is of the highest importance in regard to sanitary conditions, for on the weight of evidence given on either side at a trial at law or equity the pecuniary results may prove serious, and in some cases ruinous to the parties concerned. We are glad to be able to give some interesting results lately communicated to the Academy of Sciences at Paris, which promise, to some extent, a solution of the difficulties which the problem presents.

There are chiefly two tests by which the sanitary character of water, either of the ordinary supply, of wells, or of the effluent of a sewage farm, or the chemical treatment of sewage, may be estimated, viz., that of the physiological effects, and that by chemical analysis. The physiological method is that which is evidenced by the production of a certain class of diseases of the typhoid form from the use of impure water, of which instances are too familiar to require description. They exist in almost every large town; and, in fact, show the necessity of instant action for their prevention. But the physiological test is only of use as an indication of evil. It is, therefore, essentially followed by the che-

mical examination, which, as we have just stated, is at once difficult and uncertain.

Careful observation, however, has shown that all the diseases of the kind to which we have referred, are invariably associated with the presence of decomposing bodies containing nitrogen, either in the water supply or sewage. The source of this nitrogen is, for all practical purposes, as invariably derived from the refuse of animal existence. This nitrogeneous refuse is composed of nitrogen, hydrogen, carbon, and oxygen. The ultimate products of the decomposition of such refuse are ammonia, carbonic acid, nitrates, and nitrites. Now these latter are all harmless *per se*. It is at the intermediate stage—that is, the conversion of the refuse into these products—that danger arises to the animal system. But the presence of sulphur adds another element of danger, for by its respective combinations with hydrogen [sulphuretted hydrogen] and with nitrogen and hydrogen [sulphide of ammonium], the two most dangerous gases which we have here named in brackets, as products, are afforded. But for our present purpose we entirely omit the consideration of the sulphur compounds.

It is evident, therefore, that if the chemist detect ammonia, nitrates, and nitrites in any water, he may conclude that animal nitrogeneous matter has been the cause of their production. As a rule this conclusion is invariably arrived at, as will be seen in the weekly or other reports of water-examiners, medical officers of health of our large towns. But as will be presently seen, other causes of the presence of ammonia exist, utterly unconnected with the animal nitrogeneous refuse. It is this point to which we wish to draw special attention in the present article.

In England and France numerous instances have occurred in which gas works have been blamed for rendering water impure. In France actions have been brought and damages obtained against the companies who have been charged with injuring wells, etc., by the infiltration of water from their works. M. Boussingault has recently presented a paper to the Academy of Sciences, in which the experiment and results obtained by M. Musculus are fully detailed. Aware of the difficulty of the subject that chemist endeavored to find a test by which the injury to well or other water could be distinguished as caused by sewage or gas waste, and his plan may be briefly explained as follows:

In examining water thus rendered impure he supposes that the presence of ammonia has hitherto been the crucial test of the cause of the pollution. But sewage water invariably, if freshly produced, contains urea, while gas-refuse liquid contains none. If, therefore, urea be found in the liquid it would certainly point out to sewage as the source of contamination. But urea, on decomposing, produces ammonia, which is also contained in gas refuse, as above stated. He, therefore, sought for a means of detecting urea, and has succeeded in producing a kind of test-paper which seems well adapted for the purpose.

It appears from his researches that while urine is undergoing alkaline putrefaction small globules of a fermenting body are precipitated to the bottom of the vessel, and it is to these that the conversion of the urea into carbonate of ammonia is due. He pours the whole of the urine into a filter. At first the liquid filters rapidly, but gradually passes much slower. This he ascribes to the globules of ferment obstructing the pores of the filter, and remaining therein. The filter is then washed with distilled water to remove all trace of alkali, and carefully dried at a temperature of 35 deg. to 40 deg. C. It should be colored with a little tincture of turmeric, again dried, and then enclosed in a dry vessel to keep it from the action of moisture. The paper thus contains in its pores the globules of ferment, which are inactive so long as they are kept dry.

To use the paper as a test for urea, a piece is immersed in the suspected liquid. Small brown spots will appear if urea be present, because by the action of the ferment it is converted into ammonia, which thus shows the usual alkaline reaction on the turmeric, and as the quantity of the ammonia increases the paper will gradually become browned wherever a globule of ferment exists. It is necessary to remove all alkaline carbonates previously in the liquid by dilute sulphuric acid, or deceptive results, arising from their action, would be afforded. He has attempted to make this method a means of discovering the total amount of urea present in a liquid. For this purpose a piece of paper is placed in it, a little tincture of litmus, and as much dilute sulphuric acid as will give the liquid the tint of the peel of an onion. The whole

is to be heated for 5 or 6 hours to a temperature of 25 deg. to 30 deg. C. By the fermentation produced the urea will be converted into carbonate of ammonia, and hence by the usual method the amount of urea may be calculated. According to M. Musculus, the presence of uric acid, of albumenoid substances, and neutral salts, does not affect the accuracy of the results obtained.

Such is an outline of the plan proposed by that chemist. It is evident, on consideration, that it affords, so far as can be at present known, a very ready test for the cause of impurities in wells, brooks, etc., in respect to the refuse of gas works and sewage contamination. Its great value consists in distinguishing the source of the nitrogen in the form of ammonia. We learn from the researches of Lehmann and others that an adult fed on average animal and vegetable food will void about 500 grains of urea daily; one on purely vegetable food about 348 grains; and one on purely animal food about 821 grains, falling to but 240 grains in a person using food from which nitrogen was carefully excluded. The average of urea in urine is about 14.25 parts in 1,000 of the liquid.

Some very interesting points suggest themselves in this new method. Its value in distinguishing the difference between the effects of impurity arising from gas refuse and sewage, will be of great importance in jurisprudence. But as bearing on the results of various processes of treating sewage by irrigation, precipitation, or other means, it seems to open out a large field of inquiry that may be of essential service in controlling other methods of chemical analysis. The errors which we have seen in respect to the latter, as applied to effluent water of any of the existing sewage processes during the last three or four years, would hardly be credited by our readers, whether we refer to the ability of, or the mistakes which have been made by, various analysts. Perhaps M. Musculus may have put us in a new direction that may afford more satisfactory results than have been as yet attained.

ENGINEERING—ITS EFFECT UPON ART.*

From "The Builder."

Mr. Driver commenced his paper by giving a definition of art. Art, he said, was old, and dated from the first mention of man. He contended that it was universal and essentially human. The results of the work of many birds, insects, and animals were artistic, but in carrying out their work they were but following a line of action they were unable to alter. Art was therefore, human in that it was confined to man. All alterations of form and color done with an intelligent idea of arrangement was art, and therefore all manufacture was art. Wherever man was found, there also was art to be found, in some shape or other. Good works of art were rarely imitations. The design or art of manufacture was the choosing and placing of form and color so as to enhance all the other forms and colors to which it was opposed. Fine art was that in which the hand, head, and heart of man worked together; and the effect of that combination was seen in painting, sculpture, music, and poetry. As in art, so in engineering: it could be traced to the earliest period of the world's history; it could be taken to mean the art or science of construction; it was only another name for construction, and it was, therefore, universal. Nothing was too vast, nor was anything too small, to be undertaken by the engineer. A people might live without painting, sculpture, music, or poetry, although it would be a dreary world without them; but it would be utterly impossible to exist without the mighty science of engineering. It was the most necessary, and the root and foundation of all sciences. Neither the astronomer, the chemist, nor the artist could do without it. It was difficult to say how dependent the art of war was upon engineering. Art and engineering had been at all times coexistent, but while art was dependent upon engineering, the reverse was not the case. Many of the grandest artistic effects had been produced not so much by the architect as by the engineer; the roads, aqueducts, and other great works of the Romans fully

* A paper read before the members of the Civil and Mechanical Engineers' Society, by Mr. Driver.

proved what great engineers they were. In the grand old cathedrals there was to be seen the evidence of the engineering knowledge of our forefathers. Engineering had both a good and a bad effect upon art. As one of its good effects, might be mentioned printing. The thoughts and the words of poets, philosophers, and other great men, which at one time were confined to a very few persons, were now so nullified as to be brought within the reach of almost every one. By the multiplication of artistic works, both art, artists, and the art-loving public were greatly benefited. It was also true that there were evil effects upon art caused by engineering; but whatever they were they resulted from misapplication. When it ceased to be truthful, when it endeavored to make an inferior material represent and pass for a superior material, then it had an evil effect. Speaking of the relative position of engineering and art, he said he did not wish to place the former above the latter. Art was the superior of engineering, which should be the servant of art. Art should supply the master-mind, and engineering should be a useful workman. In conclusion, Mr. Driver spoke in favor of combining the work of architects and engineers together. He considered that each should know something of the other's work, and he believed that it would be very advantageous for a practising engineer to have an architect as a partner, and *vice versa*. He also believed that young engineers would be greatly benefited by giving some portion of their time to free-hand drawing.

A discussion followed the reading of the paper, in which Mr. Usill alluded to the difficulty of the engineer to produce an artistic work, owing to the very low price all contracts were taken at.

Mr. Whittaker was in favor of architects and engineers keeping to their own work.

Mr. Haughton referred to the difference between the art of construction and fine art, with the latter of which the engineer had nothing to do. By familiarizing himself, by the study of beautiful buildings and works of art, with an idea of what was a beautiful object, the engineer would be able to carry out his work in a more artistic manner. The buildings in London, he believed, would be erected in a superior style if the people of London were less deficient in their love of art.

THE CURRENT OF ARCHITECTURAL TASTE—THE STYLE OF THE FUTURE.

By G. HUSKISSON GUILLAUME.

From "The Building News."

In Mr. E. M. Barry's able lectures on Architecture, delivered at the Royal Academy, there is much for the student to reflect upon before he commits himself to a line of thought, or to any of those particular channels of art-fashion which are now so madly running their career. Leadership in art is now the ambition of the rising young architect, though, it is to be feared, an ambition attendant with risks and pitfalls, and, at any rate, with a very uncertain destination. Striking novelties must be the order of the day, no matter of what kind; whether borrowed, stolen outright from a remote age, burlesqued with a mixture of oddities, or as burlesquely rendered by the most serious and correct of Mediæval revivalists. Hence leaders must be found to supply the demand; a temptation is at once offered to those who have something new, or it may be something extremely old, to introduce. No matter what the motive may be—conceit, wealth, popularity—so long as the idea is startling and vivid, there is a good chance for any enterprising young architect to supersede an already "well run" leader. The chances may be against him, but he can wait till an opportunity opens. To stem the current of an already popular fashion is not to be accomplished by an effort of mere denunciation or even reason, so much as by substituting a new one. Our fair friends, or those of them who lead the *beau monde*, know this; and can change the fashions whenever they can introduce a novelty, however far-fetched and extravagant it may be. In a fast age it is impossible to check this "ringing of changes," and, viewing the matter from the standpoint of human

nature, it is quite as impossible as it would be to lay down an iron rule in politics or Church government. We shall always have differences of habit, feeling, and taste; and as long as these exist, leadership in art and in politics must exist also. But changes are nevertheless determined by demands such as those created by civilization, utility, etc. It would be idle to deny this. The most rapid changes are those which spring from human needs; opposites are hit upon tentatively, not because they are required to meet the necessity, but because they, by a law of human instinct, give the immediate relief of our nature. So it was when the cold and bare theology of the last century was succeeded by the ritualism and objective form now in vogue; or when Classical correctness was superseded by an extravagant plunge into the opposite vortex of libertinism in art and literature. The change in both cases was beneficial only as avoiding the extreme and its attendant result. The popular mind, not seeing the exact condition it required, hastily took the leap, to be afterwards corrected. Thus the popular taste for art vibrates between opposites, though imperceptibly following the grander law of equilibration. From a pedantry for Classic reproduction to the liberty of individual caprice we have unquestionably gained a freedom and a flexibility which will enable us to make the next movement still more approximate to our actual condition. It is not at all likely we shall retrace our steps, or return to the Art of Greece or Rome. It is more possible that the Queen Anne style, with all its defects, may be the next tentative, or perhaps some other equally remote approach to Classicism or Gothicism.

Now the popular taste is, as I have said, more easily led than educated. It is so in everything—legislative reform, ministerial mutations, Church government, social improvements, are all the direct or indirect effects of sudden changes, not preconcerted or well considered, but the impulses of leadership in itself as blind as any of the narrow conceits of art and fashion. But where the shoe pinches the remedy is quickly applied. In matters of fine art the remedy is slower.

As leadership, then, is at the root of art changes, we should expect at least some forethought on the part of those who set a new fashion. Architects, of all men, know the wants of mankind; utility lies at the root of their art, and we have a right to expect from them tentatives that shall not be wanting in the essentials of building, or in the higher motives of design. It would be folly not to expect another change as imminent in art as soon as we have something to introduce. It is a question only of what kind the next style will be. As I have said, it will not be a return to Greek or Roman art; it cannot be a further movement in the Mediæval direction; it may be Romanesque perhaps, Anglo-Italian, or some modification of the Renaissance; but whatever it be, it will depend upon architects themselves whether it shall be one in the right direction—a long-lived or fleeting one. This will depend primarily upon the application of that one test—namely, the sanction of utility. If our architects are to mould the new change, it is to be hoped that a discernment of the twofold capacity of architecture will be uppermost—that the scientific aspect of the change will take precedence, not the merely artistic; the progressive "idea," not the archæological.

The new "style," or change, whichever we call it (we prefer the latter), may, for aught we know, be one strictly scientific, springing from the tentative solution of new materials and modes of construction; if so, we should cordially welcome the change. Feeling and sentiment have been so worked to extremes by the ultra-Mediævalists, it would not be surprising if science this time claims the next prerogative for popular acceptance. We shall at any rate be leaping from one extreme to the other, and this appears, as we have seen, to be a condition of a past age. If the surmise be right, how are the young architects (putting aside their elder brothers) prepared? Will not the engineer stand the best chance of solving the problem, now that architects' heads are so muddled and hampered by an *embarras de richesses* of all "styles" and "ages?"

Mr. Barry's remarks in his recent lectures ably seconded our own which we have made from time to time. Church restoration—the seductions of antiquity—have robbed our rising generation of architects of what should have been their inalienable property in art, and another and fast-rising young profession have appropriated it. We mean the use of iron, artificial stone, new modes of construction,

and the thousand appliances and inventions science has thrown in our way. Until the rising architects see this—unblinded by the traditions of their profession,—and endeavor to make these their own, what chance do they hope to get from the future? The public will not be always satisfied by Greek temples, Chinese pagodas, and monkish churches and houses; their next demand will be for something altogether new, applicable to the wants of the age, and upon our young architects will remain the responsibility of moulding the next change or current of ideas into a form that shall be worthy of this nineteenth century, and not an ill-devised fashion which must be as quickly supplanted.

THE POSSIBLE IN COAL MINING.

From "The Engineer."

Some statements made not long since by Mr. Robert Hunt, Keeper of the Mining Records at the School of Mines, Jermyn street, in a communication by him to the Statistical Society, have been rather inexactly reported in some of the daily papers, as quoted in our own "Notes and Memoranda" of a few impressions back. What Mr. Hunt actually did state in reference to the limit in depth at which coal could be worked was this: Referring to his own past observations, conducted in concert with Mr. R. Were Fox, in the mine shafts of Cornwall, he roughly summarized his results as to the rate of increment of temperature with depth, by stating that for the first 100 fathoms in depth below the plane of invariable temperature, the increment of temperature was about 1 deg. Fah. for each 50 ft. in depth; that for the next 100 fathoms it was at the rate of 1 deg. Fah. for 70 ft., and for the next, or third 100 fathoms, at the rate of 1 deg. Fah. for 85 ft. in depth. The increase of temperature with depth in the metallic mines of Cornwall thus appears to be a decreasing series, and the temperature to be reached at some much greater depth might prove much below that calculated on the common assumption that the rate of increment is constant, and amounts to 1 deg. Fah. for each 50 ft. of descent. In reference to the limit in depth of coal working, Mr. Hunt also stated that coal mining was at present actually carried on in certain pits in Belgium at a depth of about 4,000 ft. From these quite independent facts he drew the inferences—first, that if coal working can be carried on profitably in Belgium at a depth of 4,000 ft., it may reasonably be assumed that it could be carried on in Great Britain at the same depth, and not improbably at even a greater one; secondly, that if the rate of increment of temperature with depth be a decreasing series in the coal measures, as it appears to be in the Cornish mineral bearing rocks, the limit for coal working might yet prove a good deal lower than had been very commonly predicted. We think these deductions perfectly legitimate, bearing in mind, however, that there are many extraneous causes present amongst the mineral lodes and mine workings of Cornwall, as pointed out in the writings of Mr. Fox and Mr. Hunt themselves, tending to perturb the rate of increment of hypogeal temperature, which either do not exist at all, or to a much less extent in the coal measures and in the shafts and ways of coal pits. Some of these disturbing conditions, more especially chemical action induced or increased by the access of surface or sea waters to the lodes, and possible electric currents, giving rise to chemical changes in the same, are of a nature to warrant the supposition that they should be less active as the depth becomes much increased; but these conditions have less application to the coal measures.

Our present object is chiefly to draw attention to some results of very recent researches, which render our predictions within narrow limits as to the temperatures that may be met with at any given depths greater than have yet been actually reached much less certain than before, and which point to conditions that may prove favorable or the contrary to the anticipations of those who urge that we may yet win coal profitably at depths vastly exceeding those hitherto reached. Men can possibly work for a short spell, aided by free ventilation, in an air temperature approaching 100 deg. Fah., but labor under such conditions is killing; and for continuous work in coal mining the limit of endurance is probably reached—at

least for white men—at about 80 deg. Fah., at which temperature the air of the working might be maintained by known methods of ventilation, though the rock or other solid walls around are even at 100 deg., or possibly more, at some small depth from their surfaces. An eminent natural philosopher, indeed, on addressing a Scottish geological society, is reported to have said that at whatever depth or temperature down to the lowest at which coal might exist, there it could be worked; that the question was merely one of adequate local cooling by ventilation with air previously artificially cooled. This, however, seems to be a mere mathematician's view of the matter, for, practically, coal will cease to be workable, whether physically possible or not, as soon as the total cost of bringing it to bank at any given locality exceeds that at which it can be brought there from some distant locality where the total charges, plus the carriage, are smaller.

It is thus of much more practical importance to discover the temperature likely to be met with at the extreme depths at which in other respects coal can be won and worked in our British coal measures, than to speculate upon what extreme of high temperature may find the limit of human endurance in hewing and getting it. It is not devoid of interest, however, to inquire what may be the limit in depth at which coal can exist at all, admitting the common assumption that hypogeal temperature, for many miles in depth at least, continues to increase at the rate of 1 deg. Fah. for each 50 ft. of descent. The experimental facts—some of very old date being known to Gensanne, a French chemist and metallurgist, very early in the last century—upon which one of the most lucrative and important chemical manufactures of the present day, viz., that of Young's patent coal paraffine, depends—prove that at a temperature far below redness, or between 700 deg. and 800 deg. Fah., coal is rapidly decomposed, not as in the red-hot gas retort, mainly into inflammable gases and coke, but into various solid and liquid hydrocarbons, with little gas and little coke. The same sort of decomposition, indeed, goes on very slowly at far lower temperatures, as is evidenced constantly in some of our more "fiery" seams of soft and rich bituminous coal, and more or less in all coal stored in large heaps, especially if aided by the presence of moisture. At half the temperature employed in Young's process of distillation, namely, at temperatures between those at which tin and lead melt, decomposition into liquid and solid hydrocarbons still goes on, though less rapidly. On the preceding assumption, therefore, it follows that at a maximum depth of 40,000 ft. coal as such cannot exist, and it is not probable that—even aided by the superincumbent pressure and in quite dry seams—it can have a permanent existence at even half that depth. At such great depths as between four and eight miles or more, coal, at the temperatures assumed, would probably be replaced by hydrocarbons like native naphtha or petroleum. It is indeed highly probable that such a process of natural distillation, which has occupied ages in completion, has been the origin of the mineral oil wells of the United States, of the great deposits of ozokerite in the lignite formations of Germany, and of many fossil hydrocarbons known to science. The depth of the sedimentary strata is so great that it is not impossible that coal beds existing as the lowest members of the carboniferous formation may be buried to a depth of even five-and-twenty miles from some parts of the surface. There is good reason to suppose that the great Westphalian coal-field which dips to the north may, like our own Newcastle field, extend beneath the North Sea, and, if so, exist there at a depth of many miles. But in that case, at depths exceeding four or five miles, it is not coal, but petroleum, that probably fills the seams. And this may be true as to seams *now* existing at very much shallower depths, if at some former period they have been covered to much greater depths by formations since removed by denudation. We may therefore conclude with some assurance, that whatever may be the increased powers of working, that science and inventive progress may place in the hands of our posterity, the limit of coal working can never be required to reach more than three or four miles from the surface. All this proceeds upon the rate of increment of hypogeal heat long commonly admitted by geologists. The researches of Sir William Thompson and of some others as to hypogeal temperature have tended to throw considerable doubt upon the longer admissibility of the view, adopted on certainly very insufficient data, that such a rate of increment could be true for great depths. Observations made during the last 50 years have, on the other hand, proved that this rate of increment is

by no means true for all parts of the globe. Nor it is even the same for not far distant shafts, or mines, or artesian wells. Nor does it hold good in some observed instances for the same shaft at different parts of its depth. These discrepancies caused the late Mr. Hopkins, of Cambridge, who examined the subject closely, to conclude that there was some unknown cause which disturbed the rate of increment of heat, irrespective of and in addition to the causes pointed out by him—the chief of these being a difference of conductivity for subterranean heat prevailing in different strata or superposed formations.

In a remarkable paper read before the Royal Society in June, 1873, "On the Nature and Origin of Volcanic Heat," and since published in the "Philosophical Transactions" for that year, a solution has been given of that "unknown cause" which it is highly probable is the true one, and which attributes the variations of hypogeal increment to the variable amounts of work transformed into heat in the different strata constituting the outer crust of our globe, by their tangential compression, produced by the contraction of our planet in its secular cooling, the resistance to which compression varies in different strata, and so also the heat of its transformation.

Space prevents our attempting to develop further here this curious and important deduction. We can only refer such of our readers as are interested to the paper itself; but meanwhile, from the abstract and profound investigations to which we have referred, two practical inferences consolatory to the future seeker for coal at greater depths than have been yet attempted may be extracted—first, that it is improbable that the temperature in descending does increase as fast as commonly imagined; secondly, that localities exist in which the rate of increment is *slower* than in others, and *vice versa*; and that it is possible to predict situations—whether in coal measures or in other formations—within which the rate of increment shall be found the least within the whole area of choice.

STEEL AS A BUILDING MATERIAL.

From "The Building News."

It can hardly be questioned that the great International Exhibition of 1851 gave a great and permanent stimulus to every branch of British manufacture, and that for the last twenty years there has been a steady progress visible in nearly every kind of workmanship both as regards quality and cheapness of production; but in scarcely any branch of manufacture has the advance been so marked as in that of steel. Formerly the labor and cost of converting iron into steel was so great that its value in the market was out of all proportion to that of common iron, and its application was confined to the cutler's art, the making of tools, and occasionally to some portions of machinery which required to be of a hard and durable nature. At the present time we find that steel is used in the largest parts of engines, in the tires of wheels for locomotives, for boiler-plates, railway bars, girders, and cannons; and that the price of cast steel is not more than double that of wrought iron.

Much of this great change, and of the extension of steel to large works, is owing to the improvements which have been introduced by Bessemer, Siemens, and others, into the process of converting common pig-iron into good cast steel. The material technically called "steel" is compounded of two ingredients, namely, pure iron and carbon, the proportion of the latter varying from $\frac{3}{8}$ to $1\frac{1}{2}$ per cent., according to the quality of steel required and the uses to which it is intended to be put, the smaller quantity of carbon producing a tough and ductile metal, and the larger quantity one that has great tensile strength, but is at the same time hard and brittle. The process employed for producing the finer kinds of steel from crude iron which is still in use, and was until the last 20 years the only one known, is a long and expensive one, occupying 15 to 20 days, and a large amount of labor in the manipulation.

The pig-iron is melted, refined and puddled, in order to remove the surplus carbon as well as all other impurities by oxidization; it is then hammered or rolled into bars of malleable iron, and again purified by manipulation in a charcoal furnace. Pure iron being thus obtained, the bars are packed with powdered carbon in large

chests of fire-brick, and kept at a white heat for several days. The material has now been transformed into "blister steel," the bars are broken up into small pieces and sorted according to their quality, then melted in crucibles holding 40 lbs. each by placing them in a powerful air furnace; after exposure to heat for three hours the crucibles are removed from the furnace and the metal poured into moulds, forming ingots of cast steel ready for working up into any required form. In this operation the consumption of fuel is about 4 tons of coke to every ton of metal that is melted; and when large ingots are required several crucibles have to be used, and a continuous stream kept up from them in succession, so that the risk and expense are greatly increased.

Steel in large masses is now required by the engineer and machinist for structures or engines subjected to heavier strains than ordinary iron will bear without yielding. For such purposes steel must be of sufficient toughness to allow of being twisted or bent cold into almost any form without injuring the fibre, whether the force is applied gradually or by sudden impact. Its tensile strength must be at least half as much again as that of the best wrought iron, and it must be soft enough to be turned readily in a lathe, bored, or cut by file and chisel. The kind of cast steel which is wanted for engineering purposes is one that will take any form in the moulding machine or under the steam hammer; yield readily and quickly to the action of cutting and shaping machines, and yet retain all the toughness of the best malleable iron with a great increase in tensile strength. The process adopted by Mr. Bessemer is one that enables the manufacturer to judge to a nicety what kind of steel he is producing, and to regulate the operations so as to obtain exactly the quality he requires. The crude pig-iron is converted into cast steel by one process which occupies not more than 30 minutes of time. It is first melted in a reverberating furnace and then run into the converting vessel, the interior of which has first been heated by coke under an air blast driven in through perforations or tubes called "tuyeres" in the bottom of the vessel. The converter being supported at the centre on pivots, can be reversed at pleasure, and when it has been heated sufficiently it is turned over to allow the unburnt coke to fall out; being then turned on its side the melted iron is poured in, and the blast turned on; the vessel is then righted and the air rushes up through the numerous tuyeres into the molten mass and sets it in violent agitation. The silicon which the iron contains first combines with the air and with some oxide of iron, and forms a fluid silicate of oxide of iron, the whole of the silicon being oxidized in a few minutes by gradually increasing the heat. When the silicon has been got rid of, the carbon of the iron unites freely with the oxygen, producing intense combustion with violent ebullition, and exposing a very large surface of metal to the air; and the flame rushing from the top indicates to the experienced workman the condition of the molten mass within. Just as the metal is approaching the condition of malleable iron, the blowing is stopped and a small but carefully measured amount of charcoal-made pig-iron, having a known proportion of carbon in its substance, is introduced into the converter, and in a few minutes the whole mass becomes steel of the desired degree of carburation. It is then poured into casting-ladles which have plugs of fire-clay fitted into the bottom so that the metal can be drawn therefrom into the moulds without being mixed with any floating impurities. The whole process, from the time of pouring the melted pig-iron into the converter to the time of casting the ingots of steel, occupies only 30 minutes, and instead of pounds of metal only being produced, as in the old process, we get tons; no fuel is required in the manufacture beyond that used in melting the crude iron and heating the converter, and there is no manipulation whatever in the whole operation. When small quantities of steel are made, the loss of weight upon the crude pig-iron used in its manufacture is somewhat about 14 per cent., but when made in large masses the loss can be reduced to 10 per cent.

It is possible, by means of the steam-hammer and the rolling-mill, to give steel a tensile strength three times as great as that of wrought iron; but the material thus operated upon is too hard and unyielding for the purposes of the engineer, the most useful metal being that whose tensile strength is from 40 to 50 tons per sq. in., and the proportion of carbon from five-eighths to three-quarters per cent. This ratio gives a steel possessing a maximum degree of toughness, yielding to any extent

without snapping, but requiring a far greater force to bend it than wrought-iron does; it is also capable of bearing heavy blows without being fractured, and is less liable to crystallize by vibration than any other metal. When the proportion of carbon exceeds three-fourths per cent., the metal has a greater tensile and compressive strength, but it loses its toughness and becomes too hard and brittle to be worked with the hammer or chisel.

Siemens' method of converting iron into steel consists in melting wrought iron in a bath of liquid pig-iron, the whole being made into steel by means of very high temperature and the non-oxidizing flame of the regenerative gas furnace. The decarburized iron is thrown in measured quantities at regular intervals into the bath of pig-iron, the operation being completed by an addition of pig-iron which contains manganese in known proportion.

By either the Bessemer or the Siemens process large castings of steel can be obtained which, without having to undergo the process of hammering, rolling, or any other mechanical compression, possess a high degree of strength and tenacity, and having no liability to fracture under heavy blows even during the most severe cold of winter.

We will now briefly allude to the uses to which this valuable material has been turned by the engineer and architect, and consider what further application to constructive purposes it is capable of. Cast steel into which the proper proportion of carbon has been infused possesses all the excellent properties of wrought iron in a high degree, and is at the same time free from the defects of that metal; so that it can be employed for every mechanical and constructive purpose where great ductility, tenacity, incompressibility and transverse strength are required. Hitherto it has chiefly been used in the construction of various parts of machines, steam-boilers being made with steel plates 5-16 in. thick which will safely bear a constant pressure of 100 lbs. on the sq. in.; it is also used for the tubular boilers of locomotives, and for these purposes it is admirably adapted, since the rivet holes can be punched close together without fear of splitting the small strip of metal between them. Fireboxes of locomotives are made by rolling a sheet of steel from a cast ingot and then hammering it up so as to make it perfectly free from all joinings or weldings. Steel is entirely superseding iron for the tires and axles of locomotive wheels, also in the shafts, cranks, and piston-rods of marine and other large engines; for the cylinders of hydraulic presses, the blades of screw propellers, cogged wheels, and for nearly all parts of machinery which are subjected to heavy strain or constant friction. Steel rails for the permanent way of railroads are now being used in the place of ordinary rolled iron ones, especially where the traffic is very heavy, it being found that a good steel rail will last nearly twenty times as long as one of rolled iron, so that not only a great saving is effected in the expense of the material itself, but also in the labor required in laying and repairing the line. Plates of cast steel are extensively used instead of iron for shipbuilding, by which means the weight of the vessel can be diminished at the same time that its strength and durability are increased; and there is little doubt that on this account steel will eventually take the place of iron for the armoring of men of war, as it has already done in the construction of the heaviest ordnance with which those vessels are armed.

Steel wire rope is used for lifting heavy loads, as in hoisting cranes and for other purposes where great tensile strength is required; it has also been employed in the Albert Bridge at Chelsea for the catenary or curved cable from which the slanting chains are suspended by vertical rods in order to preserve their equilibrium; this cable is 6 in. in diameter, and consists of a series of strands of straight steel wires bound together by a smaller one coiled over them. Steel has for some years been employed as the material of coiling shutters, which are lighter and more durable when made of this material than of any other.

In the main parts of building constructions steel is gradually being introduced, solid pillars of this material having a great advantage over those of cast iron, taking up less room, and being able to bear with safety a weight much nearer the breaking load than those of iron will do: so that even if they are bent under the load they will return to their original straightness as soon as the load is lightened, and the elasticity not be injured by the extra strain. Another great advantage possessed by columns of steel is their non-liability to

fracture from sudden blows; they are also capable of standing any amount of heat in case the building in which they stand should take fire; nor will they be liable to fracture if cold water is thrown upon them when in a heated state. The strength of steel columns may be considered as double that of solid cast iron ones of equal size, when the length is equal to about 30 diameters, and still more than that when the length is greater in proportion to the diameter.

Since steel can be rolled or hammered into railway bars, joists of similar section can be advantageously employed for fire-proof floors, and having double the strength of wrought iron, they will not be more costly even if the price per ton is double, while they will press with only half the weight upon the wall. These may be made to rest upon I or box girders, formed of steel plates riveted together, the lower flange of such girders being twice the area of section of the upper flange; since the resistance to tension is only half the resistance to compression. Such a floor, containing only half the weight of metal that would be required if common iron was used, will bear safely a greater load, since the elastic limit is much nearer the breaking weight in steel than in iron, and its elasticity is unimpaired by a load that will cause considerable flexure. Girders and joists made of steel would not be twisted and destroyed by fire, as those of cast or wrought iron are; so that for large warehouses no better material can be employed. Roofs having their frame-work of steel would be exceedingly light and durable; the parts in tension, such as horizontal and vertical tie-bars, might, in fact, be of steel wire rope, and those in compression, of round or square bars.

Much more might be said as to the advantages to be derived from an extended use of cast steel in the construction of buildings, and it is to be hoped that architects will not be behind the engineers in applying so useful a material, especially as the numerous experiments which have been made by Fairbairn, Kirkaldy, and many others, enable us to judge of the merits of the various qualities and kinds of steel that can be produced.

GUN CARRIAGES AND MECHANICAL APPLIANCES FOR WORKING HEAVY ORDNANCE.*

From "The Engineer."

Owing to the increase in the size and power of ordnance since the introduction of armor, gun-carriages had gradually become elaborate machines, and the appliances for working the monster ordnance now in contemplation would tax all the resources of mechanical science. The first difficulty experienced in mounting the Armstrong rifled guns arose from the much greater violence of their recoil as compared with that of the old cast-iron guns; a disadvantage mainly resulting from their superiority in lightness, strength for strength. A self-acting brake for arresting recoil, designed and successfully tried at Elswick, in 1864, by the Ordnance Select Committee, on a 70-pounder timber carriage, was described. The great superiority of wrought iron to timber as a material for gun-carriages was next referred to, and experiments made in 1865 were cited, as showing the error of the popular objection entertained against wrought iron, on the score of its producing, when struck by shot, more numerous and destructive splinters than timber.

Some of the leading types of gun-carriages made at the Elswick Works both for naval and for land service were then described, commencing with the plate compresser or recoil brake, which was stated to have been adopted almost universally, and by nearly every Power in the world.

The series included the 12-ton gun broadside carriage, also the 18-ton gun naval carriage and slide of similar construction, but capable of revolving about a rear pivot as well as a front one, so that the gun might be shifted from one port to another adjoining, and be used in both. The special feature of the plan was the pivoting of a portion of the rack, by which means it could be made available for training the gun in both ports. This rendered unnecessary the turn-table now used for the same purpose, which was held to be objectionable in a ship; for a

* From a paper read before the Institution of Civil Engineers by G. W. Rendel, C. E.

large hole had to be made in the deck, the deck beams must be cut and space occupied below, besides which a serious and costly complication in the structure of the vessel was introduced.

In the 15-ton gun wrought iron carriage and slide for land service, attention was directed to the method of training the platform, and to the substitution for the usual tripping rollers under the carriage of a number of grooved rollers, permanently running on the slide. The training was effected by gear connecting the platform trucks on the front and rear rails in such a way as to drive them at a speed proportioned to the respective radii of the rails. The result was that the platform moved truly about the centre of both rail circles, required no actual pivot, and was trained with ease and rapidity by the simple traction of the wheels. By placing the carriage permanently on wheels, and trusting more to the compresser to arrest recoil, the operation of "tripping" the carriage, *i. e.*, of throwing the wheels into action for running out, was avoided, thus saving time, labor and exposure of men.

By the adoption of these mechanical arrangements, for the application of manual power to the working ordnance, guns up to 25 tons weight could now be worked with more ease, safety and rapidity, than guns of a fifth of that weight were formerly. The size of ordnance continued, however, to increase by rapid strides. There were already many rifled guns in existence of 36 tons or 38 tons weight, throwing 700 lbs. shot. Guns of nearly double that weight were actually being made, and there was no manufacturing obstacle to the construction of still larger guns. It was difficult, indeed, to place a limit to the size of guns that could be produced on a system like that of Sir William Armstrong, under which the gun was built up of concentric cylinders superposed in layers, whose number might be increased so as to form an immense total thickness, without involving any one piece of unmanageable dimensions. The powder pressure attained with large charges would, possibly, first impose a limit on the size of guns; but recent experiments and investigations gave ground for the belief that, even with charges vastly exceeding any yet used, the powder pressure might be regulated and kept within prescribed bounds. Hence, then, the adoption of some inanimate power in the place of mere hand labor, for loading and working heavy ordnance, desirable as it was for existing guns, became an absolute necessity for guns of the immediate future. The simplicity and compactness of hydraulic machinery, and the perfect control it gave over heavy weights, especially adapted it for the purpose. Hydraulic power sufficient for the heaviest gun might be transmitted through a very small pipe, for long distances and by intricate ways; so that a steam pumping engine might be placed in a fort or ship in such position as to be absolutely secure, and supply power, by this means, for working many guns. A detailed description was then given of some of the arrangements experimented with, or now in progress, for loading and working guns by hydraulic machinery. These arrangements embraced a new system of mounting turret guns, in which the carriage was dispensed with, and the gun was supported on three points, viz., on a pair of trunnions placed well forward and on a saddle under the breech itself. The trunnion arms rested in two sliding blocks, which ran in guides on fixed beams built on the floor of the turret. Immediatley behind each block in the direct line of recoil were two hydraulic cylinders for checking recoil and running the gun in or out. The saddle which supported the breech slide along a beam or table beneath it. The front of the beam could be raised or lowered by a hydraulic press to give any desired elevation, but the rear was pivoted at a point corresponding to the horizontal position of the gun; consequently the gun returned always to the horizontal position as it recoiled, whatever elevation it might be fired with, and cleared the port in coming back. Thus the advantage of muzzle pivoting, viz., the reduction of the size of the port-hole, was to a large extent realized without the necessity of lifting and lowering the gun itself.

In the system of mechanical loading for guns mounted in turrets, the gun was revolved and brought to a fixed loading position, when it was sponged and the charge rammed home by hydraulic power. The shot was brought up to the loading place on a small railway truck, controlled by a friction-plate, which clamped it to the rails whenever the truck-handle was lowered. It was then run on to a hoist, which rose between guides against stops, and brought the shot opposite the gun muzzle ready for being rammed home by the hydraulic rammer, consisting of a parallel tube in which

ran a piston and tubular piston-rod. The head of the rammer formed a sponge for cleansing the bore, and contained a self-acting valve which opened when pushed against the end of the bore and discharged a strong jet of water within the gun. A jointed rammer, used for positions where there was not sufficient space for the tubular rammer, was also described. The advantages attained by this arrangement were as follows:—The loading operation was transferred from a confined space and exposed position in the port of the turret to a roomy and convenient place on the main deck, where the apparatus was completely protected; the dimensions of the turret were greatly reduced; one man in the turret and one outside might direct and control all the movements of a pair of the heaviest guns, and might load and fire them without other help than that involved in bringing up the ammunition; and, finally, far greater rapidity of fire was attainable than would be possible by manual power. With reference to the necessity the system involved of turning the turret round always to one of two or three fixed loading positions, it was stated that the turrets of the Devastation made a full turn in 45 seconds, and that a railway swing bridge over the Ouse, constructed under the direction of Mr. Harrison, Pres. Inst. C. E., and weighing 800 tons, was turned with almost equal facility by means of hydraulic machinery. It was also stated, as a matter of fact, that the whole operation of bringing to loading position, sponging, loading, and placing again in firing position a 9in. 250-pounder turret gun, mounted experimentally on this plan, had been effected in 23 sec. The jointed rammer had been successfully applied on a garrison platform. In this case, as the rammer was fixed on the platform, there was no necessity for turning the gun to a definite loading position, and the loading gear and men working it were protected by the parapet. By the present method of loading barbette guns by hand, the men had to mount upon the platform in full view of an enemy, and besides being exposed to shell fire, they became the targets for a rifle fire, which, owing to the precision and range now attained with rifles, would render it difficult to keep guns in effective action under such circumstances.

In suggesting another plan for the application of a hydraulic system of loading in casemates, it was stated that there was no doubt more difficulty in the adoption of mechanical loading in existing casemate forts than in turrets or open earthworks. The size of artillery had so outgrown that of the existing forts during the long time necessarily expended in their construction that 38-ton guns had now to be mounted, if possible, in batteries originally intended for 12½-ton guns. But this fact made it only more imperative to dispense with manual power, because the larger guns, while they further restricted the already limited space, required larger crews. The service by large numbers of men of heavy guns closely ranged in confined casemates, tier upon tier, might lead to serious confusion in the heat of action; and the necessity of crowding men in time of war in isolated forts was of itself a grave evil. By substituting hydraulic for manual power for working the guns, nine-tenths of the men might be dispensed with, and the work might be done more coolly, rapidly, and efficiently. Rapidity of fire was nowhere of greater importance than in the case of guns designed to prevent the passage of swift steamers past fixed batteries; and economy of men was a vital consideration in the defence of a coast so extended as that of the United Kingdom. It was said that already far more guns were mounted than could be manned. Modern artillery could only be worked with highly trained men, whom it would be impossible to produce upon short notice. Nor could the present small force be made effective by activity in shifting men to threatened points, for the attacks of steam fleets would be sudden and unexpected, and could only be met by preparations at all points.

The introduction of an effective system of mechanical loading had an important bearing on the question of the comparative merits of breech and muzzle loading, because it enabled a gun, however long in the bore, to be loaded at the muzzle with at least as great facility as at the breech, while dispensing with the complications of breech mechanism and the time required to work it, both of which became important considerations in the case of monster ordnance.

The principle of sinking guns entirely under cover from horizontal fire behind any sufficient parapet, and raising them only to deliver their fire, possessed the great advantage of making earthwork defences available. All defences must yield to continued attack; and an iron fort when

seriously injured could scarcely be made good before the end of a war, and only then at great cost. It was the especial merit of earthwork, that it might be easily strengthened and adapted to new circumstances, and that it might be repaired almost as fast as it was destroyed. In the two forms of gun-carriage adapted for this system of protection, which had been proposed by Major Moncrieff, the principle was the storing and utilizing of recoil, in the one case by the raising of a weight, in the other by the compression of the air. The economical value of the utilization of recoil was insignificant where steam-power was available.

The main object to be obtained by the utilization of recoil was to make of each gun-carriage a machine complete in itself, and independent of any connection with other machinery for producing the required power. In a system, however, of hydraulic gun-carriages, supplied with power from steam pumps, the connection between the carriage and the source of power was the simplest kind, consisting only of a small pipe which might be furnished with a stop valve, and thus enable the power to be turned on or off with nearly as much facility as a jet of gas. As there was no limit to the amount of power that might be conveyed, so there was no restriction of the height of cover obtainable—an important point in the employment of earthwork as a protection for guns, since the crest of the parapet might easely be cut down by the enemy's fire. A drawing was exhibited of a 12½-ton gun mounted under cover of earthwork, so as to be raised to the firing position by hydraulic power, and the advantage of using a power independent of recoil for raising the gun was illustrated by the height of cover obtained. A working model was also exhibited of a 38-ton gun similarly mounted, as designed for the upper deck barbette battery of H. M. S. Téméraire—a vessel which, being intended for ocean cruising and provided in consequence with masts and sails, required a high deck and could not carry a revolving turret.

ON THE CONSTRUCTION OF A NEW MEAN NOON SUN DIAL.

By S. V. CLEVENGER.

Written for Van Nostrand's Magazine.

A self-equating dial may be constructed in the following manner:

Consider the gnomon as an upright pencil, perpendicular to a plane surface.

Determine the meridian line upon the surface passing through the pencil where it intersects the plane at right angles. (Chauvenet's "Spherical Astronomy," pp.429, 430, vol. i.

With the centre of the pencil as the centre of an arc of equations of time, describe 15′ angles radiating both sides the meridian line, making 16 of them on each side.

Find where the shadow of the pencil point will fall at mean noon, along the proper equation line upon a given day and in the given latitude, by taking the calculated apparent altitude of the sun at local mean noon, the rays being taken as secant to the gnomon, the shadows forming tangents to the pencil with its point as centre, and thus easily calculated.

Where these mean-noon shadow-points fall upon the plane surface, marks may be made and a continuous line drawn joining the points. In these latitudes this line forms a figure 8 with the ellipse nearest the stylus much smaller than the other, which is broader and elongated.

It facilitates observations to have the seasons painted nearest those parts of the line over which the shadow point passes at mean noon.

The gnomon may be constructed in a variety of forms. I have one on a dial, the base of the stylus of which springs from the north end of the surface and is arched above the figure, overhanging the centre of the equation arc with an adjustable point 5 in. from that spot. The advantage being in having but little of the dial shadowed during the noon hour.

It is interesting to calculate the various forms the mean noon line assumes in north and south latitudes.

The figure may be calculated for a given latitude, and used anywhere by inclining it at an angle equal to the difference of latitudes.

I first constructed one of these dials in A. D. 1869, and found it gave satisfactory time for all ordinary purposes. Several newspapers noticed my invention of the instrument at that date, but this is the first effort made to properly give its construction to the scientific world.

A machine can readily be made which would plot the line quicker than it could be calculated.

THE CHANNEL TUNNEL.*

From "The Architect."

For many years mining has been carried on under the sea. In Cornwall, in Cumberland, and in Northumberland, lead, silver, and coal have been won from strata under the sea, and in some instances the working has been so near the bottom that the action of the waves could be distinctly heard in the galleries. In Cornwall, at the Bottallach and Levant mines, galleries are driven considerable distances from the coast, and with the side galleries form a network some score of miles in length, and in some parts with a very thin stratum of rock between them and the sea. In Cumberland the galleries of one pit are between five and six thousand yards in length, and extend in a direct line more than 4,000 yards under the sea, yet the manager states that only an inappreciable quantity of sea water finds its way into the mine. Then, again, it is fifty years since Sir Isambard Brunel projected the Thames Tunnel, which, constructed for carriage and foot traffic, has recently been converted into a railway tunnel, and trains are now running through it every few minutes daily, and within a very few feet of the bottom of the river, which is here 1,200 ft. in width. The soil above the tunnel is of the loosest character, mud, gravel and sand, and in some parts not 20 ft. thick. This tunnel, the first constructed under a tidal river, and having for a considerable portion of its length 50 ft. of water above it, is now as sound and water-tight as any, and more so than many tunnels constructed inland.

Among the various tunnels which have been made for railways, one or two may be mentioned where difficulties arising from an excessive influx of water have been successfully overcome. The Kilsby Tunnel, from which for many weeks 1,800 gallons of water were pumped per minute, by the employment of 1,250 men, and 13 steam engines, was successfully driven at a cost of £145 per yard. The Saltwood and the Bletchingly Tunnels were also driven, in the face of great difficulties, at a cost of £118 per yard, at which rates 22 miles would cost £5,650,000 and £4,568,000 respectively. The Hauenstein Tunnel, in Switzerland, a very difficult work, cost £80 per yard. Ordinary railway tunnels, through chalk and such like strata, cost from £30 to £50 per yard.

Since the completion of these tunnels the art of tunnelling has advanced considerably, and with the aid of machinery to facilitate the operations of the workmen, and of arrangements for the supply of fresh air, it appears that no difficulty exists in piercing the hardest rocks and in forcing a way through them of almost any length.

The most interesting instances recently completed are, the tunnel under Mont Cenis, 9 miles in length, at a cost £206 per yard; and the Hoosac Tunnel, in America, nearly 6 miles in length, at a cost of about £180 per yard, both for the most part through very hard rock; and there are now three in progress—one under the Severn, a deep tidal river, 5 miles in length under the direction of Sir John Hawkshaw; another under the Mersey, under Mr. Brunlees; and the third under the St. Gothard, 10 miles in length, where the rate of progress is much more rapid than was made under Mont Cenis, the most recent return being at a rate of 14.6 ft. per day on the two faces. This increased rate of excavation is due to improvements made in M. Sommeiller's machinery, the result of the experience gained during its use in the Mont Cenis Tunnel. But M. Favre's rate of progress under the St. Gothard will be much exceeded by the use of Major Beaumont's new apparatus, and this rate will again be very much surpassed when working in the grey chalk, which forms the bed of the sea between Dover and Calais, by the use of Mr. Brunton's machine. All these machines are driven by compressed air, which, after driving the machinery, is used for the ventilation of the tunnel.

It has, then, been established during the progress of these tunnels, that tunnels of the size required for railways can be driven through strata whether consisting of loose soil or the hardest rocks, and that the powerful machinery employed, driven by compressed air, provides an adequate suppy of air for ventilation during construction.

Having thus referred to what has already been done in tunnelling for railway purposes, let me now call your attention to

* Abstract of a paper read before the Society of Arts, by W. M. Hawes, F. G. S.

the Submarine Tunnel proposed to be constructed under the Straits of Dover, but which, while exceeding all others in length, will not, from the nature of the stratum through which it will be excavated, occupy more time or involve greater difficulties than have been overcome in driving the tunnel under the Mont Cenis. The character of the stratum through which the Channel Tunnel is to be driven must determine not only the cost and the time required for its execution, but its practicability, and has therefore demanded the most serious and careful consideration by Sir John Hawkshaw and Mr. Brunlees, as well as by their French colleagues.

It appears to be generally acknowledged that the only place where a submarine tunnel can be made with a due regard to safety and economy is through the grey chalk which stretches across the straits between Dover and Calais, and, this being admitted, it only remains to show the cost of, and the time required for, the construction of a tunnel of such dimensions and length as to be practically available for general traffic.

First, as to time. The application of the machine for tunnelling through chalk or any soft strata, invented by Mr. Brunton, will so reduce the time required for the excavation of the tunnel between Dover and Calais that the period for the completion of the twenty-two miles may be determined almost to a certainty. At Snodland, near Maidstone, where it has been tried, a heading of 7 ft. in diameter was driven at the rate of 1 yard per hour. This rate, supposing the work to be begun on both sides of the Channel, would require only two years to drive a driftway from 7 to 9 ft. in diameter across the Channel; but, allowing for the delays and casualties which always occur in works of such magnitude, we may safely say it would be easily completed in two years and a half.

The machine has been fairly tested, and the simplicity of its arrangement affords the best guarantee of its successful application to working through a soft, plastic material like the lower or grey chalk. The action of the machine is twofold. It chips away the material from the face of the chalk by an unceasing operation, and it collects the débris produced, deposits it on a band, and finally delivers it into the wagons which are to convey it away.

With such a machine the cost of the excavation of the driftway may be accurately estimated. The cost of the tunnelling machines, the air-pumps and pumping engines for drainage and for raising the chalk as excavated, can be easily determined. The hand labor to be employed is also capable of accurate estimate, and would be limited in amount, as the tunnelling machinery would be worked by compressed air, which, whilst driving the machine, would also ventilate the driftway; and the charge for interest on capital and for management during construction can be fixed and limited.

The most careful calculations estimate the cost of the driftway at £1,000,000. The driftway being completed, the cost and time required for its enlargement to the size of a railway tunnel could also be as easily estimated; and it may be assumed that should the driftway be driven successfully 1 or 2 miles under the sea, the enlargement might be begun without waiting for its completion across the Channel.

If this course be pursued, the entire work may be completed in five or six years, and at a cost of from six or eight millions of money; but until the driftway be carried a certain distance under the sea, it is almost impossible to give more than a general idea of the time which would be occupied in completing the work, or the expenditure it would involve.

The shafts on each shore will be sunk to the depth of 450 ft. below high water mark. From the bottom of the shaft driftways will be driven for the drainage of the works whilst in progress, and for its permanent drainage after completion.

The tunnel will commence 200 ft. above this driftway, and will be driven at an inclination of 1 ft. in 80 to the junction with the drainage driftway, and then at a gradient of 1 to 2,640 to the centre of the straits, where the tunnel from the English shore will meet that driven exactly in the same manner from the French shore, and, being united with it, will complete the submarine railway under the Channel. The drainage will be from the centre of the tunnel to either end.

At present I have only referred to ventilation during construction, respecting which, so long as the excavating power is obtained by the use of compressed air, there is no difficulty. The results obtained during the construction of the Mount Cenis and St. Gothard Tunnels are conclu-

sive on this point. But for the ventilation after completion, I will confine myself to the statement of our distinguished engineers, that there can be no difficulty in obtaining by mechanical means a steady current of air through the tunnel at all times, quite sufficient to maintain the purity of the atmosphere. The exact method by which this will be accomplished need not be stated at present; it is sufficient to know that there is a general agreement of opinion by the English and French engineers as to the facility with which perfect ventilation can be maintained.

It is proposed, then, to establish in France and England companies to raise £160,000, and to begin the works on both sides at once; and so soon as the driftway is bored a sufficient distance under the sea to prove the accuracy of the calculations of the English and French engineers, and the practicability of the work, to take measures to bring this great undertaking before the various governments and capitals interested in its success, with a view to the ultimate provision of capital for its completion.

Sir J. Hawkshaw expressed his opinion that the project was practicable, and would one day be accomplished. The capital of £10,000,000 seemed large, but that included some miles of railway, both on the English and French shores, and the cost per mile would not come near the cost of the Metropolitan and District railways. The practicablility of the project would be tested by an experiment that would not be very costly.

Mr. Bateman said he was anxious to see the project carried out; but it presented so many uncertainties and so many difficulties, that he could not recommend the attempt to be made. No human being could say that there was not some dislocation or fissure in the submarine line between Dover and Calais, and if such were the case, no human power could contend with the pressure of some 400 ft. of water from an ocean channel. He thought the project was hazardous, and would prove a failure.

Mr. Rawlinson did not think there was any reason to suspect the existence of a fissure in the bed of the channel. It seemed to him that Mr. Bateman blew hot and cold on the question.

Mr. Lawrence suggested that twenty-five borings should be made to test the bed of the channel. That could be done for £25,000. Mr. Jones, Mr. Baird, and others continued the discussion; after which a vote of thanks was passed to Mr. Hawes for his Paper.

THE APPROXIMATE VALUE OF A REDUCTION OF RULING OR MAXIMUM GRADES.*

By JOHN G. CLARKE, C. E.

At the request of some professional friends, the following method of obtaining approximately the value of the reduction of a ruling or maximum grade on a railroad, is respectfully submitted for the consideration of the Society. For the basis of the paper, the writer is indebted to the late Charles Ellet, Jr.

The want long felt by engineers on location, of some method by which they may feel assured that the expenditure which they make to reduce the ruling grade is legitimate and proper, has given birth to many empirical formulas, none of which, so far as known, are at all satisfactory. It is not claimed that the formula now presented is exact; because the very foundation—the amount of business that the road shall do—is conjectural; and in order to obtain a formula which can be applied readily, values which are not mathematically accurate are admitted; but these errors are of small importance, and it is thought that when a pretty close estimate of the value of the grade, upon the conjecture that it is to do a certain amount of business, is arrived at, it will be near enough for all practical purposes.

The value of the reduction being the effect which such reduction will have on the cost of transportation, this cost is divided under three heads:

First.—The cost of repairs, etc., to road (not including cost of relaying track). This is evidently *constant per mile.*

Second.—Deterioration, caused by transportation of materials; as repairs to track due to weight of freight; expense of re-

*Transactions of Am. So. of Civil Engineers.

pairing and renewing cars; also expense of agents, force of all kinds, and contingencies, with interest on cost of cars; the items under this head are *constant per ton per mile.*

Third.—Locomotive power. This embraces expense of repairs to track due to weight of engine and tender; cost of repairing and renewing engine and tender; interest on first cost; cost of fuel, etc., and wages of engineman, fireman, and conductor. This item of cost is *very nearly constant per mile run by the engine*, and, for this discussion, is assumed at 40 cents; the proper number for one class of engines would, of course, be slightly changed for another, but the variation from the average is not large.

In speaking of quantities as constant, it is evidently meant that they will be constant for any particular road, regardless of grade; they will, of course, vary with each road, depending upon locality, management, traffic, etc. The cost of the items under the first two heads being independent of the grade, its value is therefore to be measured by the reduction of the cost of motive power which it entails, or what is the same, the reduction of the total number of miles which the engines are obliged to travel in consequence of being able to carry the larger load; and thus, it is not the height of the summits, but the *rate* of ascent that is to be considered.

Let W represent the gross weight in tons in full trains, carried annually one mile in the direction opposed to the maximum grade, and A represent the average gross load in tons an engine can draw up this grade; then $\frac{2\,W}{A}$ will equal the number of miles the engines travel annually, and $\frac{2\,W}{A} \times 0.40 = \frac{4\,W}{5\,A}$, will be the annual cost of motive power in dollars.

The rolling friction of car wheels being taken at $\frac{1}{2\,0}$ of the weight, or about 6 lbs. per ton, the force of gravity and friction on a grade of 16 ft. per mile is twice the resistance of friction on a level; on a 32-ft. grade, three times; on a 48-ft. grade, four times, etc. Then if T equal the gross load an engine can draw on a level, and X equal the maximum grade—

$$T \times \frac{16}{16 + X} = A,$$

and as on low grades the weight of the engine is small in proportion to the weight of the train which it draws—in order to obtain a formula which can be used—its weight may be assumed to vary with the weight of the train, and thus the formula found above may be applied to the train alone, without considering the weight of the engine.

In the very able report of Mr. Silas Seymour, on the change of grade on the Union Pacific R. R., west of Omaha, he carefully worked out a table showing the number of cars his engines would haul on different grades, in which he has even taken into consideration the effect of the wind on his train moving at a given velocity; below is a table giving Mr. Seymour's loads in cars on grades from 10 to 80 ft., and opposite, the numbers of cars given by the above equation, discarding from it the weight of the engine:

Grades.	Seymour's Report.		Formula.	
Feet.	Cars.	Differences.	Cars.	Differences.
0	94		94	
10	56	38	58	36
20	40	16	42	16
30	30½	9½	32½	9½
40	25	5½	27	5½
50	20½	4½	23	4
60	17	3½	19½	3½
70	15	2	17	2½
80	13	2	15½	2½

By this table it will be observed that the differences between Mr. Seymour's figures, which are accepted as accurate, and those given by the formula, are nearly alike; and, therefore, the calculated values of any modification of grade from either column will be almost identical for any grade less than 100 ft. per mile.

Substitute in the expression of the annual cost of the motive power in dollars, $\frac{4\,W}{5\,A}$, the value of A, just found, and it becomes $\frac{16+X}{20\,T}\,W$. Now, if X assume a new value, X^1, the difference in cost of motive power between the two grades will be

$$\frac{16+X^1}{20\,T}\,W - \frac{16+X}{20\,T}\,W = \frac{X^1 - X}{20\,T}\,W.$$

For application, let $X^1 - X = 1$, then $\frac{W}{20\,T}$ will be the increment in the annual working cost for each foot of the grade.

As an example—assume 940 tons, the load which Mr. Seymour takes as the gross load an engine can draw on a level on his road, then $\frac{W}{20\ T} = \frac{W}{18,800}$; capitalize this (money taken at 7 per cent.), and $\frac{1}{18,800} \times \frac{100}{7} = \frac{1}{1,316}$ of a dollar will be the value per ton per mile for each foot taken from the ruling grade. The engine stage west of Omaha is reported to be 145 miles long, and it is presumed that this is found to be the economical run for the engine; if Mr. Seymour's figures, 112,800 tons, for the probable business to be done against the heavy grade, are taken as the gross tonnage conveyed through in the direction of the grade, the sum one would be justified in spending to reduce the grade 10 ft., will be $\frac{112,800 \times 145 \times 10}{1,316} = \$124,286.$

Mr. Wilson Crosby—The line on the Union Pacific Railroad, between Omaha and the Elkhorn river, as at first adopted, showed grades of 66 ft. per mile, ascending westward in two instances, and 80 ft. per mile ascending eastward in three instances; and so distributed that the engine power required to work this part of the road would practically have to run over the whole distance between Omaha and the Elkhorn, 23 miles.* By this formula the value of a reduction of 10 ft. in the ruling grade with the assumed movement of 112,800 tons against it annually, would be

$$\frac{112,800 \times 23 \times 10}{1,316} = \$19,714$$

instead of $124,286, obtained by supposing the engines to all run a distance of 145 miles west of Omaha. If the grades were made to conform to 30 ft. per mile rising west beyond the Elkhorn river, the amount of expenditure justifiable to accomplish this then would be

$$\frac{112,809 \times 23 \times (66-30)}{1,316} = \$70,971.$$

* West of Elkhorn the grades were level, or ascending gently westward. As the idea of reducing the grades between Omaha and the Elkhorn to 30 ft. per mile was entertained, it is presumable that those in the Platte Valley did not exceed this limit, and that 30 ft. per mile, rising west, may be taken as the rolling grade on all except the section between Omaha and the Elkhorn.

The annual business to be anticipated when converted into freight car-loads, according to Mr. Seymour's standard, gives 45,000 car-loads westward and 34,700 car-loads eastward (including the return of empty cars). By reference to the table it will be seen that an amount of force capable of transporting 45,000 car-loads up grades of 66 ft. per mile, will be more than sufficient to haul 31,700 car-loads in the opposite direction up grades of 80 ft. per mile. For this proportion of traffic 30 ft. per mile ascending east would be an equivalent to 30 ft. ascending west. The 66 ft. rising west is the ruling grade on this part of the road as located originally.

IRON AND STEEL INSTITUTE.

PRESIDENT ISAAC LOWTHIAN BELL'S ADDRESS.

Responding to an invitation of unmistakable cordiality, the Institute held its last meeting at Liége. The terms of the request that we should visit our Belgian friends justified great expectations, but these fell far short of the actual arrangements made for our reception. On arriving at this important seat of the Continental iron trade, the military and municipal authorities of the town assembled to do honor to the British representatives of an industry so peculiarly its own. Private as well as public hospitality did their utmost to render our sojourn one continuous festival, and this of so attractive a nature that it may be doubted whether the more severe labors of the Institute were not, in consequence, somewhat neglected. It could not, however, fail to be highly agreeable, as well as instructive, to have an opportunity of observing that the same spirit of frank communication of ideas which marks our intercourse with each other met us at every turn on the banks of the Meuse. The office of assuring us of the pleasure our presence afforded all classes of the community was undertaken by gentlemen distinguished in science or art, and our expedition to Belgium was one of the rare, if not the only occasion, where the sovereign of a country identified himself with his people in offering a genuine welcome to so numerous an embassy of peace. Those of our body who had the opportunity of enjoying the magnificent hospitality of his Majesty the King of the Belgians, will understand and appreciate the nature of the union which binds that enlightened monarch with subjects whose labors, like our own, combine individual prosperity with national progress.

At this, the commencement of another session, I have been induced, at the suggestion of certain members of our Council, to submit to this meeting a few matters of general interest to those engaged in the manufacture of iron in its different stages. This idea arose, in the first instance, from a natural wish to receive some information on the extent of the progress which had been made in mechanical puddling.

It will be in the recollection of all, that, at our Dudley meeting, a paper was read on this interesting subject by Mr. Samuel Danks. The account he gave of the success, in the United States, of the revolving furnace which bears his name, was such that, under the auspices of the Institute, a Commission was sent across the Atlantic to judge from personal examination of the performance of this invention. Moreover, in order to test the stability of the Danks furnace for puddling the iron of this country, quantities of pig from different localities were sent out to be operated upon in presence of the gentlemen who had to report upon the mode in which it effected its duty.

In all respects, the accounts received from our commissioners were so satisfactory that certain firms made arrangements for giving the system a proper trial in this country. These were:—

Messrs. Bolckow, Vaughan & Company, Limited, Middlesbrough, who speedily had two experimental furnaces in operation.

Messrs. Hopkins, Gilkes & Company, Limited, by whom has been erected a complete forge, comprising two melting cupolas, twelve revolving furnaces with powerful shingling machine, and a set of three-high rolls for reducing the blooms into bars.

The Erimus Iron Company, also at Middlesbrough, who have built a complete forge, consisting of twelve furnaces, to which is now being added a finishing mill for working up the product into merchantable iron.

The North of England Industrial Iron Company, at their works, near Stockton, erected a forge consisting of eight furnaces with the requisite machinery for obtaining puddled bars.

In addition to these establishments on the Tees or its neighborhood, Mr. Robert Heath has constructed six furnaces in North Staffordshire.

It is not my intention to go into any details of the actual results which have been obtained at the various establishments in which the trials themselves have been made; at the same time, I feel sure that every one present will most thankfully receive any information with which those possessing, and authorized to communicate it, may favor the meeting.

As the preliminary investigation, however, into the merits of the Danks furnace was undertaken at the instance of the Institute itself, I deemed it my duty, in the absence of other communication on the subject, to make some inquiry into what had up to this time been done. I did this in the hope that, when I brought it before you, some gentlemen would avail themselves of the opportunity by stating their opinion of what we might expect from the proposed supersession of the more laborious part of the puddling process by mechanical agency.

Speaking generally, then, I may be allowed to observe that at no previous period in the history of the iron trade would this change have been more welcome than during that which intervened between the meeting in 1871, when Mr. Danks read his paper, and the present time. For a considerable portion of it, not only have we had the price of labor rising to a point hitherto unknown in the industrial annals of this country, but there was an actual want of the necessary human aid to meet the extraordinary demand made on our malleable ironworks for their produce. Within the last few months, however, a great change has taken the place of previous prosperity; but, in a commercial sense, we require, perhaps more urgently than ever, any relief which mechanical puddling can afford in a manufacture which all but, and in some cases perhaps, has ceased to be profitable, and in which serious difficulties are more than apprehended.

I fear, notwithstanding, it must be admitted that the success which has attended the substitution in this country of the new for the old plan of hand-puddling, has not invariably corresponded with the accounts given us by those gentlemen who reported upon its introduction in the United States. Nevertheless, I would not have it supposed that I am impugning in any degree the soundness of their observations while engaged in their mission. It is quite possible that American iron may offer less difficulties while under treatment in a Danks furnace than that of this country. It is also equally possible that those difficulties

which have been encountered in a continuous application of iron, such as that produced in Cleveland, may not have been so apparent when treated in more limited quantities during the comparatively short trials made under the personal superintendence of our Commissioners.

Referring, now, more particularly to the North of England, I have to observe that some alterations have even been found necessary in the moving, as well as in other portions of the machinery. These minor defects, so far as I can learn, have been overcome, and there remains the one great impediment to success, upon which, at Dudley, so much stress was laid, viz., the durability of the lining of the furnace. Upon this branch of the question, the testimony obtained in the North of England is somewhat conflicting. At one establishment, the entire plant, after some months of work, has been laid idle, and preparations are there in progress to alter the furnaces to the plan recommended and already described by Mr. Crampton, in a paper read before the Institute. On the other hand, while admitting the existence of difficulties not yet entirely vanquished, the practical men who are directing the trials express themselves confident of ultimate success.

In the puddling process, as it is generally understood, we seek to remove the substances usually associated with iron in the pig, such as silicon, sulphur, phosphorus, and carbon, by oxidation, either direct by the atmosphere, or more probably by a conversion of a portion of the iron into an oxide, which, in its turn, reacts upon substances which are well known to exercise a prejudicial influence on the properties of the metal in its malleable form. The presence of the carbon constitutes, of course, the only essential difference between cast and wrought iron, and it is possible to remove this element before the other three named substances are fully oxidized. In such a case, we will have them in greater or less quantity in the precipitated malleable iron, from which no subsequent treatment can effectually free them. Hence, no doubt, the variations observed in the quality of the product; for the strength and efficiency of the best puddler will fluctuate in so laborious an occupation as that in which he is engaged.

By the use of machinery, all irregularity in the character of the manipulation to which the iron is exposed may be avoided. Again, the use of large quantities of ore, sometimes amounting to half the weight of the metal, is probably beneficial. Certain it is that all experimenters with the Danks furnace concur in asserting the product obtained to be of superior excellence compared with the ordinary run of iron made in the furnace worked by manual labor.

There is another circumstance in connection with the manufacture, as it has been hitherto pursued, which possesses certain disadvantages. When iron of high tensile power is required, no one disputes the value of "work," as it is termed, consisting of drawing out to as great an extent as possible by the rolls, the iron under treatment. It is very questionable, however, whether any good arises from this mode of dealing with a material which has to form an object exposed to friction, and in which resistance to abrasion has to be guarded against. In such we may have a wearing surface, like that of a rail, composed of the original puddled bars, elongated until they probably do not exceed $\frac{1}{10}$ of an inch in thickness, more or less imperfectly welded. I say imperfectly welded, because there seems little doubt that the interposition of an excessive amount of the fused oxide of iron, or cinder produced in the balling furnace, offers a considerable impediment to complete union. This cinder, being imprisoned in the substance of the iron, is the origin of the occasional well-known exfoliation of the rail, from which steel, owing to the homogeneity of its texture, is entirely exempt.

Mechanical puddling, then, affords the means not only of securing iron of an improved and regular quality, but the power it commands of manipulating the metal in masses beyond the compass of human exertion will, in my opinion, tend to place an iron rail in a position more nearly approaching to one of steel. With such prospects, it cannot be doubted that our Institute did wisely in drawing the attention of manufacturers to the Danks furnace, and will act prudently in continuing to encourage every attempt to overcome those difficulties which almost invariably beset the introduction of new inventions.

Considerable importance is attached, and fairly so, to the superior yield afforded by mechanical puddling as compared with that performed by manual labor. I would point out, however, that this is secured at a certain sacrifice, for in no case do I find that

the large quantity of ore, containing 50 or 60 per cent. of iron, affords above 20; while, on the other hand, a large quantity of addi ional material has to be maintained for a considerable time at a very high temperature.

Those members who took part in the meeting held in London, in April of last year, will remember a paper by Dr. Siemens, which excited much attention at the time, "On the Manufacture of Iron and Steel by Direct Process." The information contained in it possessed much interest, not only in a commercial, but in a scientific point of view. We had described to us a furnace having the power of commanding a most intense temperature, with the novelty of the fuel, as a gas, entering, and the products of combustion leaving, by the same aperture. I have no doubt the Institute would be glad to hear whether this ingenious adaptation of the regenerative furnace, as applied to ordinary puddling, continues to afford the satisfactory results described as being obtained by Messrs. Nettleford and Chamberlain.

It would be useless to detain the meeting at any length with what are the admitted defects of the blast furnace, so far as an imperfect combustion of the fuel and the absorption by impurities and consequent deterioration of the resulting iron are concerned. Looking at what takes place in the puddling furnace, it seems reasonable to suppose that the phosphorus and sulphur, being always in the presence of more or less oxide of iron, in this direct process may never, or at all events to a much less extent, pass over to the metal.

The merit claimed by Dr. Siemens, in respect to economy of fuel to the amount he names, I must confess, stands, in my judgment, on more debatable ground. It is contended by him that the products of combustion escape from the blast furnace chiefly as carbonic oxide, at a temperature of 350 deg. C. (662 deg. F.), and that complete combustion is impossible, because each atom of carbonic acid would immediately split up into two atoms of carbonic oxide, by taking another equivalent of carbon from the coke present. It must, however, be remembered that this reaction would have to be effected in a region of the furnace where the temperature is insufficient for its accomplishment; that $\frac{1}{3}$, or thereabouts, of the fuel, does actually escape as carbonic acid, affording the full measure of heat carbon is capable of producing, and that the real barrier to its more complete combustion is the inertness, in a properly constructed furnace, of the resulting gases on the ore under treatment. Dr. Siemens does not, of course, deny the antagonistic action of carbonic acid on metallic iron; but he expects to avoid this, as well as the reduction of this carbonic acid to carbonic oxide, by exposing the fused ore to the influence of solid carbon. In this way carbonic oxide, he states, is alone produced, and then that this carbonic oxide is burnt to carbonic acid, where it meets with no carbon to split it up.

If the system propounded to us last spring admits of these conditions being fulfilled, I am ready to allow an excellent yield of metal from the ore will, in all probability, follow. I see, however, much practical difficulty in securing a state of things which I believe essential for commanding even an approximation to complete reduction of an oxide of iron.

After allowing sufficient margin, the consumption of fuel is put down at 25 cwt. per ton of iron; but conceding the perfect combustion calculated on, my own expectations are less sanguine than those of the author of the paper we are considering. No doubt, he deprives the gases escaping from his regenerator of more of their sensible heat than happens in the blast furnace; but, as I have formerly pointed out, the blast furnace does satisfactorily account for the appropriation of all the heat evolved, and, of this heat, the waste scarcely exceeds 15 per cent. In the regenerative furnace, on the other hand, we have to deal with a contrivance where a large preliminary loss has to be encountered in the "producers," and then the gas therein generated has to be burnt in a reverberatory furnace, from which, according to the experiments of Professor Krans, only 17 per cent. of real effect is obtained.

Whatever may be the ultimate destiny of the direct process as described by our colleague, I, for one, am grateful to him for the valuable information he has acquired, and communicated to us, in his experiments on the reduction of iron ore in the furnace which is known by his name. In my first address from this chair, I called attention to the immense service likely to be rendered by the regenerative furnace in the manufacture of steel, of which commodity the weight annually produced has since then

reached the important figure of 250,000 tons.

Owing to the conditions attending its production, there is no metal more liable to be contaminated by foreign matter, and none more sensitive to the influence of such foreign matter, than iron. One or two-tenths of carbon per cent. may impair its malleability, and a little above the ten-thousandth part of phosphorus, more or less, may constitute the difference between steel being manageable in its manufacture, or the reverse. On the other hand, phosphorus may exist in bar-iron, and even improve its facility of manipulation in the rolling mill, while its presence in far less quantity renders steel entirely useless. Carbon and phosphorus may then be combined separately with iron, of course, in very minute quantities, without serious injury to the product; but the question has been raised lately by M. Euverte, of Terrenoire, whether it is not the concurrent presence of these elements which exercises so fatal an effect on the quality of steel.

When Mr. Bessemer first tried to apply his steel to the production of a railway bar, his attempts in many, indeed in most cases, were unsuccessful. Subsequent investigation made it appear that the passage of so large a body of air through the melted pig, as is requisite to decarburize the iron, leaves a quantity of oxygen, either combined with, or occluded in, the iron. To remove this, a certain quantity of spiegel is added, the manganese of which absorbs and removes the oxygen as an oxide. The spiegel is thus used as the vehicle of recarburization, for, in removing the oxygen absorbed in the converter, carbon at the same time is added. M. Euverte points out that the employment of 7 cwt. of spiegel, containing 9 per cent. of manganese and 5 per cent. of carbon, to 3½ tons of Bessemer steel, gives an excess of carbon; and if less spiegel is used, the deficiency of manganese interferes with the malleability of the product. By means, however, of the substance known as ferro-manganese, which is manufactured commercially containing as much as 75 per cent. of the last-named metal, this difficulty is avoided. By its aid, M. Euverte expresses the utmost confidence in being able to declare, as a natural law, that we may introduce phosphorus into cast steel, provided carbon is eliminated, and that the less carbon, the more phosphorus may be present.

This French metallurgist does not pretend that we are entitled to infer that steels containing phosphorus are as good as those free from it; on the contrary, he recommends the use of materials containing the smallest quantity of this ingredient. Inasmuch, however, as we now possess the means of fusing wrought iron, and the presence of phosphorus—in moderate quantities, at all events—is declared by M. Euverte not to interfere with its malleability under the rolls, I have deemed the subject worthy of being brought under your notice.

The enormous advance in the market value of coal in all parts of the kingdom has invested every question relating to its economy in our various operations with the deepest importance. In the case of the blast furnace, this importance has been intensified—certainly in the North of England—not only by the unheard-of price which coke attained, but from an absolute scarcity of the article. Under the double inconvenience as to price and supply, we may regard every hundredweight of fuel per ton of iron unnecessarily consumed to have entailed a loss of two shillings, while the inability of the manufacturer to obtain this quantity diminished his make to the extent of nearly 5 per cent., and this during a period of almost unparalleled prosperity.

It is needless to say that any chance of relief, from whatever quarter it might have proceeded, was watched with much anxiety, and the possibility that superheated blast might do something in this direction, has conferred upon the fire-brick stoves a position of unusual interest.

It is some time since the subject of additional temperature in the air used in iron smelting has been before us, and, therefore, perhaps I may be allowed to say a few words on the views which have been expressed at some of our early meetings.

It was admitted on all sides that when hot air was first applied to the blast furnace, the economy of fuel far exceeded the heating power of the coal burnt in the apparatus suggested by Neilson. This result, later on, gave rise to an expectation that by every increase in the temperature of the air an economy corresponding to some extent to that first obtained would be realized. I have endeavored upon former occasions to demonstrate that the apparently inexplicable action of the hot blast was due to what was equivalent to an enlargement in

the size of the furnace. This was effected by a substitution of heat alone for heat accompanied by the products of the combustion by which it was evolved, so that, for a given quantity of heat produced, the reducing gas had, by its diminution of volume, a prolonged, and, therefore, a better opportunity of performing its office. Actual experience has confirmed this explanation, for precisely the same effects have in one instance been produced as were obtained by the use of heated air. This point in regard to capacity reached, it has been my study to prove that all additions to the temperature of the air have no more value in regard to effect than the same quantity of heat evolved by the combustion of the fuel in the furnace itself. True it is, that the nature of the combustion in a blast furnace is much less perfect than that which ordinarily takes place in the fireplaces of a hot-air stove; but against this we have the loss by escape of heat at the chimneys, radiation, etc., which numerous analyses and observations convince me is equal to half the value of the fuel consumed, while the actual waste in the blast furnace is only about one-third of this amount.

Commercially, therefore, it is only by having a fuel of much less value than that burnt in furnaces sufficiently capacious, say 12,000 to 15,000 cubic ft. and upwards, that we reap any advantage by a previous heating of the air before it reaches the tuyeres. Now, if we assume the power of a fire-brick stove to raise the temperature of the blast 500 deg. F. above that within the reach of cast-iron pipes, about 1¼ cwt. of coke is the utmost economy to be hoped for by the change, *i. e.*, provided my views on an identity of effect being produced by the combustion of the fuel in the furnace and that conveyed into its interior by the air used are correct.

Chemical reasons, to which I shall have occasion to allude, impose, in my opinion, useful limits, both as to size of furnace and temperature of blast; nevertheless, it is true that furnaces very much larger than the dimensions I have named continue to be built, and since we last discussed this somewhat complicate subject, many fire-brick stoves have been erected. I, therefore, invite any gentleman to communicate to this meeting his experience, which may justify a hope that any notable advantage is to be expected by a change in the construction of our furnaces or their adjuncts.

I have found an additional inducement in calling your attention to this interesting question, by a paper from the pen of my able and distinguished friend, Prof. Tunner. This communication has been translated and published in the last number of our "Transactions," and contains a criticism on the views I have propounded from time to time on the chemical action of the blast furnace. In particular, this learned metallurgist reminds me that the extent to which we can peroxidize the gases in the smelting process is greatly exceeded in the charcoal works of Styria and Carinthia. The subject here raised is one of great practical importance, for, in reality, upon it depends the existence of the useful limits of size of furnace and temperature of blast just alluded to.

My friend very properly admits that the law I have enunciated on the escaping gases, was confined to smelting Cleveland ironstone with coke; although I believe it is one equally applicable to most other ores where mineral fuel is used. Moreover, I did, towards the end of my work on iron smelting, call attention to the remarkable circumstance that, instead of 100 volumes of carbonic oxide being associated with 40 to 45 volumes of carbonic acid, these proportions were greatly exceeded at Eisenerz in the production of white iron from spathose ore. So doubtful was I of this, and so incredulous of the small quantity of fuel required, that Prof. Tunner, at my request, had the analysis of the gases repeated, and the performance of the furnace carefully noted. The results of this examination are given in his paper, from which it would appear a ton of white iron is obtained with 14 cwt. of charcoal, with the blast heated to only 300 deg. C. (572 F.), while the escaping gases give as much as 64 volumes of carbonic acid for every 100 volumes of carbonic oxide, or about one-half more than in any instance in my experiments. But here, again, there seems to be a limit beyond which oxidation cannot be carried, for we are told that, at Treibach, where the blast was only heated to 160 deg. to 200 deg. C. (320 to 390 deg. F.), it was doubtful whether any saving of fuel followed raising its temperature to 500 deg. C. (932 deg. F.)

In seeking for any explanation of the circumstances under which this kind of iron is thus obtained, with a consumption of fuel far below anything indicated in my own experience, I have to contend with the great

disadvantage of not having the action of a charcoal furnace to appeal to, and, in consequence, I offer an opinion on the subject with considerable reserve. My experiments, neither on spathose ore itself, nor on charcoal as a mere source of heat, lead me to think that they offer any solution to the apparent anomaly. Apart, however, from the carbon as it exists in charcoal, there is a point of dissimilarity, comparing it with coke, which is worthy of our notice. This consists in the much larger quantity of potash contained in the former, the presence of which is known to have the power of determining, at high temperatures, the union of nitrogen with carbon, and so form cyanogen. I have shown that, even in a coke furnace, owing to the condensation of this alkali in its upper region, a vast accumulation of cyanides takes place during the process of smelting. It will, therefore, only be reasonable to suppose that, inasmuch as charcoal contains a larger proportion of potash than coke, those cyanogen salts may exist in larger quantities in the furnaces examined by Prof. Tunner than in those of the North of England.

Carbonic oxide is the ordinary form in which carbon reduces iron in the blast furnace, and when one-third, or thereabouts, of a given quantity of this substance, as it exists in carbonic oxide, is converted into carbonic acid by the operation, all further action ceases. Before a similar saturation of the gases with oxygen has taken place, when the carbon is presented in the form of cyanogen, three times as much oxide of iron will have been reduced as when this agent exists as carbonic oxide.

This reasoning led me to institute a number of experiments on the behavior of cyanogen, in the presence of carbonic acid, on oxide of iron, and then to compare the results with those observed on mixtures of carbonic oxide and carbonic acid.

I found formerly, that when equal volumes of the two last-mentioned gases were passed over reduced iron at a red heat, the metal was oxidized. I also ascertained that, when oxide of iron, or ores of iron, were similarly exposed, they lost oxygen until they had a composition corresponding to protoxide. Such a mixture of these oxides of carbon is, therefore, essentially of a non-reducing description.

I have, upon previous occasions, spoken of what is in all probability an important action in the blast furnace, viz., the power of iron and its oxide to split up carbonic oxide into carbon and carbonic acid, which was described as carbon deposition or impregnation. It was found that at no temperature was carbon deposited from carbonic oxide when the mixture of gases consisted of equal volumes of carbonic acid and carbonic oxide. Indeed, the phenomenon disappeared soon after increasing the proportion of carbonic acid to one-half the volume of carbonic oxide.

Cyanogen and carbonic acid were experimented on in the proportion of one volume to six, because the relation of carbon to oxygen in such a mixture is the same as in equal volumes of carbonic oxide and carbonic acid. It was first ascertained that the mixture was unaffected by a mere exposure to heat, after which it was passed over oxide of iron at a temperature of redness for 2¾ hours. After this time the result was found to contain:—

Metallic iron		40.9
Iron combined with oxygen	31.8	
Oxygen	6.7	38.5
Carbon		20.6
		100

thus showing that reduction and carbon deposition had taken place to a large extent.

Professor Tunner proceeds to show that by raising the temperature of the blast from 200 deg. C. (392 F.), to 500 deg. C. (932 F.), the consumption of charcoal for grey iron was reduced from 23 or 24 cwt. to 19 or 20 cwt. No particulars of the composition of the gases are given, but, looking at the richness of the ore and the heat units required for its production (58,800 instead of 93,000, as in Cleveland), I feel sure the relation of carbonic acid to carbonic oxide in the escaping gases will be below that I have observed in the Middlesbrough district. It seems, therefore, possible that the high temperature indispensable for obtaining grey iron is unfavorable for the accumulation of cyanogen compounds, and hence as complete a saturation of the gases by oxygen is impracticable in the small furnaces of Styria and Carinthia, as when white iron is the object in view.

Recently, unmerited prominence, in my opinion, has been given in the "Times" newspaper to a so-called proposal to substitute chalk for coal as a source of heat. Within the last few weeks, this journal states with some emphasis, "that the ap-

plication of chalk as fuel being attended with satisfactory results has been proved by figures." This is attempted to be shown by comparing the expense of heating a church during two winters, upon one occasion with coal alone, and upon the other with a mixture of coal and chalk, and the extent of the saving is given at 50 per cent. In these figures, not a word is said of the actual rise in the temperature of the atmosphere of the building, so that the proof itself is most incomplete. I will not pretend that the heating arrangements of the church being defective, some advantage may not have been derived, although I think it unlikely, from the addition of chalk; but that the splitting up of the component parts of this substance can have otherwise than a cooling effect, is too apparent to need comment.

If there were anything in the proposal, what are the directors of the railways near London about? They are still bringing fuel from the North of England for engines which are running through a country, the entire surface of which is composed of a mineral possessing, it is said, when used with fuel, an equal heating power. Until this or some analogous exact trial is made, the inventor will have some difficulty in persuading an ironmaster to adopt his scheme for smelting, knowing, as the latter does, that he saves fuel by a preliminary calcination of the limestone he is compelled to use as a flux.

Questions of a purely trade nature do not come within the sphere of our discussion, save when the same are effected by changes in the machinery we employ, or in the processes themselves. The extraordinary nature of the fluctuation in the value of our produce, which has made itself felt within the last few months, is such as to have assumed the dimensions of a subject of national importance. This must be admitted, when we reflect that the depreciation of price in the annual production of the furnaces and mills of this country cannot be short of £20,000,000. The decline in price, although not unexpected, has been so rapid that neither employers nor men have had time to accommodate themselves to the altered state of things, and sounds of violent alarm are not uncommon as to the future of this great branch of our national industry. Fears are again expressed that some of the ironmaking States of Europe are ready to seize and retain a trade which has, in a peculiar degree, been regarded as our own. Belgium, in particular, is represented as the source of our greatest danger, and a French minister is said to have declared that France is now able to compete with England in the manufacture of iron. No one thoroughly acquainted with the natural resources of these countries, or with those of Germany, as they now stand, can imagine that there is any real ground for believing that we can be permanently disabled in our competition with any of these nations. It has been publicly announced that bar iron in some quantities has been imported into this country from Belgium. Granting this to be so, what lasting impression can that country produce on our trade, supplied, as the latter is, by 7,000 to 8,000 puddling furnaces, against less than $\frac{1}{10}$ of this number of this foreign State? Even in the matter of ore, the Belgian mines have greatly receded in their output during the last ten years, while their importations from France and other places have greatly increased. On the other hand, the quantity of pig iron sent out of this country to Belgium is 17 times what it was in 1863. But the obvious limit to such an expansion of the Continental iron trade, as seriously to threaten our position, is an actual want of sufficient coal to make the iron now being turned out of the works of this country. No doubt one great inconvenience of such an inflated state of trade as that which recently manifested itself in our particular branch, is the stimulus it affords to competition—foreign as well as domestic. Under its influence, the United States of America, in the production of iron, have advanced at a rate unknown in their previous history, and, as a consequence, the importation of rails from this country has materially declined. Our own workmen considered themselves entitled, and reasonably so, to a participation in the high prices which recently prevailed, and, naturally, they regard with little favor that change which the present state of affairs renders inevitable.

Whatever difficulty may beset us at the present moment, it can only be of a temporary character. Of raw materials we have an abundance; of our skill as manufacturers, whatever may be said to the contrary, we have no reason to be ashamed; and it will be a strange thing if, with these advantages, British energy is unable to hold its own against any people in the world.

USEFUL DISPLACEMENT OF SHIPS AS LIMITED BY WEIGHT OF STRUCTURE AND OF PROPULSIVE POWER.*

By WILLIAM FROUDE, Esq., F. R. S., Vice-President.

From "Iron."

It seems a mere truism to state that the best ship for the performance of a given duty is that in which the useful displacement bears the largest proportion to the whole displacement; yet I believe that this aspect of a ship's merits has not been as systematically investigated as it deserves, or as it is capable of being investigated. Stating the proposition broadly, and with a view to the approximate and incomplete character of the following investigation, it is not necessary to define minutely the sense in which the term *useful displacement* will be used. It is enough to regard it as that displacement which remains after deducting the dead weight (1) of the hull as completed with proper regard to structural strength, and (2) of the engine power necessary to drive the ship at the required speed, together with the coal which will be consumed on the voyage. As, however, the coal consumed per day will be approximately proportioned to the engine power, while the coal per voyage will depend upon the length of the voyage, the question whether capacity for coal should be counted as part of the useful displacement, or whether the coal carried should be regarded as dead weight, will depend on whether the merits of the ship are viewed generally, or in relation to a particular voyage.

I ought to state at starting that when the problem is treated thus broadly, and to the exclusion of such limiting conditions as are imposed, for instance, by the necessity of traversing the Suez Canal, its investigation points to the conclusion that the existing tendency towards great length, as compared with beam or with area of midship section, is only justified where extreme speed is required, speed very much greater than that which sea-going merchant ships in fact realize. My object, however, is not so much to enforce the conclusions which I have myself arrived at, as to endeavor to induce those members of the institution whose long experience and mature judgment is essential to the complete solution of the problem, to co-operate in the endeavor to arrive at something like a general, even if it be but a provisional solution of it, or at all events to see whether some very instructive and useful results cannot be arrived at, by treating it in virtue of the larger principles which underlie it; leaving for subsequent introduction those modifying peculiarities which, unduly indeed, yet not without plausibility, support the belief that every case is a special case.

Looking to the first of the two great divisions of the subject, that of dead weight due to structural strength, I am encouraged by recollecting the exhaustive and exact treatment which it received in one of its aspects, in Mr. Reed's well-known paper, which was read at the Royal Society, on "The Unequal Distribution of Weight and Support in Ships," as exemplified by the cases of the Minotaur, Northumberland, Bellerophon and Hercules. I am encouraged more by the completeness with which the principles of strain are there elucidated, than I am discouraged by the opinion to which Mr. Reed seems to incline, that it is not possible to reduce the problem to a complete general solution. For while granting fully that a *complete* general solution is impossible, it nevertheless appears to me clear that in proportion as we deal with larger and larger ships, the strains which have to be taken account of and provided for, become more exclusively those which are most amenable to calculation, and of which alone I propose to take cognizance—I mean what may be termed "sea-going strains."

In the paper which was read yesterday evening by Mr. John, the whole subject of the strains experienced by a ship in a seaway was so admirably treated, and was worked out with such quantitative exactness, based on data derived from actual ships, and far more complete than any that I possess, that I have thought it best to withdraw the detail matter I had prepared on that branch of the subject, and proceed to apply simply those fundamental principles which it appears to me must inevitably come into operation as governing the proportion of strain, and hence of structural weight, to dimension, taking Mr. John's results as a point of departure. For, if we

* From a Paper read before the Institute of Naval Architects by William Froude, Esq., F. R. S.

proceed from any one of the ships, the strains and strength of which he reduced to calculation, to a ship of the same type, but differently dimensioned, we can see very nearly how the strains and the structural weight in correspondence with them will vary in terms of the dimension.

First let us assume the length alone to vary, and let us suppose that the ship thus altered (we may for convenience say lengthened) to be subject to the operation of a proportionally lengthened wave. Then it is obvious that the volumes or weights inherent in the unequalized buoyancy which the wave creates, will be enlarged in the square of the ratio of elongation, since the areas which represent them in longitudinal section in the two cases will be similar areas, while the breadths will be the same in both cases; and since the leverage with which these volumes act in straining the ship will have also been enlarged in the ratio of the elongation, *the bending moment of the lengthened ship will be as the cube of the elongation.*

If we next assume the breadth of the ship alone to vary, it is plain that the straining weight will be enlarged in the simple ratio in which the breadth is enlarged, and the bending moment will follow the same ratio; since the leverage is unaltered, *the bending moment of the widened ship will be as the enlargement of breadth.*

Lastly, let the depth alone of the ship be assumed to vary; here it is plain that no variation of straining weight or of leverage will ensue; *the bending moment is independent of the depth.*

Finally, as regards the stress on the deck, and bottom and sides of the ship, regarded as the corresponding members of a box-girder, it is plain that in every case *the stress will be simply the bending moment divided by the depth of the ship*, and throwing all the conditions together, it follows that the stress on each member of the girder will be directly as the cube of the length, directly as the breadth, and inversely as the depth. The total sectional areas of the deck, the bottom and the sides must be proportional to the stress; and as the structural weight may be taken as proportioned to these sectional areas, multiplied by the ship's length, it must be regarded as proportional, directly to the fourth power of the length, directly to the breadth, and inversely to the depth. From this follows the remarkable result that, alike whether we enlarge a ship by increasing her three dimensions in the same given ratio throughout, so as to enlarge her displacement in the cube of that ratio, or by increasing her length alone, so as to enlarge her displacement in that ratio simply, the increase of structural weight will be as the fourth power of the enlargement of dimension. It is obvious that, in whatever degree the total dead weight of a ship's hull depends on her requirement for structural strength, this conclusion tells most unfavorably on the useful displacement of a ship enlarged simply by elongation, as compared with one enlarged in all her dimensions alike; nor can the question of first cost be unaffected by the same condition.

Turning next to the second of the two divisions of the subject—the dead weight of engine power regarded as a function of the dimensions—a full and exact general solution of this question cannot be arrived at without a more exactly detailed knowledge than we as yet possess of the law which governs resistance in terms of dimension, assuming each dimension to vary independently. Such a solution would require a knowledge of the "curve of resistance"* for the ship of each proportion. But though we do not yet possess this, I trust that the experiments I am conducting for the Admiralty will eventually supply it.

But if the ship is enlarged alike in all her dimensions, and if we know the curve of resistance for the original ship, the solution can be arrived at exactly, by a study of that single curve of resistance, or very approximately, in virtue of the "power" of the speed to which the resistance is seen to be proportional in the different parts of the curve; in either case, taking account also of the law of comparison, which, as I explained in the paper on the Greyhound, may be held to govern universally the ratio of the resistances of large and small ships built on the same model, if compared under the condition of what I have called "corresponding speeds." That "law of comparison" is that if the speeds of the ships are as the square roots of their respective dimensions, their resistances at those speeds will be as the cubes of their dimensions. The mathematical treatment of the question shows that if for speeds between a given

*That is, a curve in which, while the abscissæ express speeds, the corresponding ordinates express the resistances experienced by the ship at those speeds.

speed of the smaller ship, and the corresponding speed of the larger, the resistance of the smaller varies approximately as the power $(2+n)$ of the speed, the resistance of the large ship at the same speed as the small ship, will be that of the small ship enlarged in the ratio of the dimensional enlargement raised to the power $\left(2-\frac{n}{2}\right)$. From this it would follow that if the small ship were being driven up to a speed at which the resistance varied with the sixth power of the speed, the larger ship (if but moderately enlarged) would travel at the same speed as the small one without any increase of resistance.

I will here apply the comparison, as it would affect a ship of the Greyhound type if built of enlarged dimension. A careful examination of the curve of resistance shows that it is pretty exactly reducible to a succession of variations depending on the following powers of the speed:—

Power of Speed to which Resistance is Proportionate in "Greyhound."

	Knots.	Power.
From	0 to 5.5	2
"	5.5 to 9 5	2.5
At about	10.5	3.3
"	13.	4.5

Applying these figures in the manner described, we arrive at the following comparison between the resistances of the Greyhound and those of a larger ship of the same type, driven at the same speed. It will be observed that when the speed is the same for both ships, their horse powers will be simply proportioned to the resistance.

Growth of Horse-Power required for Constant Speed with Enlarged Dimensions.

Speed.	0. to 5 5	5.5 to 9.5	10.5	13
Power of speed to which resistance is proportional in original ship	2	2.5	3.3	4 5
Power of dimension to which resistance, or horse-power, is proportional in enlarged ship	2	1.75	1.35	0 75
Power of displacement to which resistance, or horse-power, is proportional in enlarged ship	0.67	.58	.45	0 25

It will be seen from this how very favorably the larger ship is circumstanced as regards engine power, if no enlargement of speed is contemplated. To trace out the result in connection with assumed increase of speed would lengthen the discussion inordinately.

With reference to the question of enlargement in one or other of the dimensions alone, if it consist of elongation alone, or of elongation accompanied by a relatively less enlargement in the other dimensions, though I am not in a position to tabulate the results, I feel confident that their general character would be as follows:—Assuming the typical ship to have, as most modern ships have, lines rather finer than the Greyhound, it is a mistake to suppose that, if she were simply elongated, this increased length would be unaccompanied by increase of resistance, at least unless probably such speeds as 13 knots were in contemplation. The increased surface friction inseparable from increased length, or rather from the corresponding increase of surface, inevitably produces an almost proportionally-enlarged resistance for a given speed. Now, as simple elongation has been shown to create a structural weight enlarged into the ratio of the fourth power of the elongation, while the displacement will only have been enlarged in the simple ratio of the displacement, and the engine power, and therefore engine dead weight, enlarged in nearly the same ratio, it is obvious that enlargement by elongation is, as regards useful displacement, wofully inferior to general enlargement, unless some very marked increase of speed is contemplated. I believe such ships could be made absolutely lighter if built with greater depth; and if the exigencies of the Suez Canal traffic require ships of small breadth and depth in immersed midship section, and therefore *prima facie* open to the objection I have been suggesting, it seems to me possible to meet the difficulty effectually and economically by giving greater depth amidships—adopting, in effect, something like the artificial girder structure adopted by the Americans in their long river and lake vessels, the height of freeboard, forward and aft, being regulated by the necessity of keeping the ship's ends dry, and the depth amidships being such as to meet the bending moment safely without excessive increase of structural weight.

THE PRESERVATION OF IRON STRUCTURES.

From "Iron."

Where great tenacity and toughness are not demanded, an iron containing a considerable proportion of silicon, carbon, and phosphorus, is preferable to iron of greater purity, and consequent higher price, provided always that it contains but little sulphur. The presence of much sulphur would probably neutralize the protective action of the other impurities, and I suspect that this has prevented the superiority of "bad iron" for certain uses from becoming practically understood. Every practical iron-worker can distinguish between ordinarily pure iron and that which is much less pure, but there are but few who are able to determine the source of the impurity. I strongly recommend the manufacturers of some of those brands of Cleveland pig which are comparatively free from sulphur, but are much depreciated in value on account of the phosphorus they contain, to make similar castings from theirs and higher-priced irons, and by exposing them equally to atmospheric action, compare the rate of corrosion of each.

If my theoretical anticipations are sound, the result of such trials will prove the superiority of these irons for many important purposes, such as cast water pipes, spouting, many kinds of ornamental work, etc.

The most obvious device for defending iron against surface corrosion is the coating it with some kind of adherent film, which is more or less capable of resisting atmospheric action. There are two distinct classes of such coverings—first, those which are dissolved in some liquid are applied cold, and slowly solidify by evaporation or chemical change; and second, those which are fused are applied hot, and solidify on cooling.

Of the first class the most common are paints and varnishes. These are so numerous that a separate examination of each would form a treatise in itself. I must, therefore, refer only in general terms to the properties of the most important. A paint consists of two chief components, the liquid medium and the solid body, the body being ultimately mixed, but not dissolved in the medium. Thus, in ordinary white paint, the body is carbonate of lead or "white lead," and the medium is linseed oil alone, or more commonly a mixture of linseed oil and turpentine. Turpentine is a volatile oil, *i. e.*, one of those oils which, when pure, evaporate away so entirely that if a piece of paper is wetted by them, and then exposed to the air, no film or stain is left behind. Therefore, if the body were mixed in pure turpentine, the paint would be worthless, as, on drying, the body would be left behind as a mere dry powder that could be readily brushed away. The use of the turpentine is merely to dilute the linseed oil, which is the true binding medium, and to hasten the drying, the paint being thinned or weakened in proportion to the quantity of turpentine that is used. It is important that this should be clearly understood by all who use ordinary paint for the protection of iron.

Linseed oil is quite different. It is a fixed oil, *i. e.*, it does not pass away by evaporation at ordinary temperatures, it cannot be boiled away nor distilled by heating it under ordinary atmospheric pressure, because its boiling point under such pressure is higher than its dissociation point, or the temperature at which it is decomposed by heat. But it does dry somehow; in this drying property it differs from ordinary fixed oils, such as olive oil, etc., and thus belongs to another subdivision of the fixed oils, viz., the "drying oils." How then does it dry if not by the ordinary process of evaporation, such as effects the drying of water, spirits, volatile oils, and most other liquids? This question is answered by the fact that it contains about 80 per cent. of a very curious liquid to which the name of linoleine has been given. This linoleine, when exposed to the air, slowly combines with oxygen, and is thereby converted into a solid substance of translucent resinous appearance, and possessing much of the toughness and elasticity of india-rubber or gutta-percha, though long exposure to light and a moderate degree of heat, such as that of the direct sun's rays, renders it harder and rather brittle. It is adhesive, remarkably impervious to water, and very difficult of solution either in essential oils, spirits, naphtha, or even bisulphide of carbon. Another important and valuable property of this linoleine is, that it expands in drying. This expansion is a simple result of its combination with oxygen, which increases both

its weight and bulk. The difference between a varnish and a paint may now be understood as it should be, for the distinction is not merely theoretical, but has some important practical bearings.

In varnishes the solid or body is *dissolved* in the medium, and the drying (with one or two exceptions, where a drying oil is the solvent) is effected by the evaporation of this medium. Gums, resins, or those intermediate vegetable products called "gum-resins," usually constitute the soluble solid of varnishes, and the medium is a volatile oil, spirit, or similar liquid. The solution forms an unctuous adhesive liquid which, when spread out, becomes, on drying, a solid resinous film.

It will be seen from this that there is a remarkable difference between the drying of a paint having the linoleine of drying oil for its medium, and the drying of a varnish, the medium of which is volatile, and dries by evaporation. In the latter there is a loss and *shrinkage* in drying; in the case of the linoleine there is a gain (of oxygen) and an expansion. The importance of this, where the object is the protection of iron from corrosion, is very great, for the *shrinkage* of the resinous film of the varnish is liable to destroy its continuity, and form minute cracks through which atmospheric agents may reach the iron. This tendency to cracking is increased by the expansion and contraction to which metals are subject from variations of temperature. The thicker the layer of varnish the greater is the liability to cracking and peeling.

The reader who is well versed in metal work will probably object to this by quoting the common and successful use of a true varnish—viz., solution of gumlac or shellac in alcohol—for the lacquering or preservation of brass. But this same lacquer affords so little aid in the preservation of iron that, although it may be easily applied, it is very rarely used for the purpose of preserving iron or steel. This, I suspect, arises from the peculiar insinuating character of the oxidation of iron, due, as already explained, to the fact that the iron rust itself acts as an oxygen carrier. Every crack, pore or other flaw in the varnish, however small and invisible to the naked eye, becomes a centre of corrosion, from which the oxidation spreads downwards and radially, undermining all around. This undermining of the film is the more effective from the fact that the rust occupies a much greater bulk than the iron itself, and thus in swelling it must uplift and peel off the brittle film of shellac or other varnish, by a sort of microscopic eruption.

This inward spreading and undermining action of iron rust is the main source of the difficulty of protecting it by paints or varnishes. Even the continuous linoleine film, in spite of its compactness, and the increased substantiability afforded by the body of the paint, gradually loses its toughness, curls up and peels off, revealing below a stratum of oxide which has somehow formed in spite of it. It is quite possible that the fully oxidized linoleine may give up some of its oxygen to the iron surface which it covers. This idea is, however, purely speculative, as the subject does not appear to have been directly investigated.

The mechanical adhesion of the protecting film is, of course, a matter of primary importance. Certain substances are said to be "*sticky*," and this adhesiveness is very commonly regarded as an absolute quality. This is a great mistake. The adhesive affinities of any and every substance, whether solid, liquid or gaseous, vary according to the second body with which it comes in contact. If we take a common pair of scales, balance them, and then allow one of the pans to touch the surface of the water in a saucer, we shall find that it adheres to the surface of the water with considerable force. This force may be accurately measured by gradually adding weights to the other pan until the adhesion gives way, and the beam is tipped in the direction of the weighted pan. By varying the experiments and using flat discs instead of the pan, we may learn whether water adheres with equal or varying force to different solids.

The discs may be of, say, iron, steel, copper, tin, zinc, silver, brass, glass, etc.; if all are of the same shape and of equal size, and balanced before touching the water, the weight required respectively for effecting their detachment measures their respective forces of adhesion. These will be found to be curiously different. If we now acidulate the water, then make it alkaline, afterwards substitute it by alcohol, oils, ether, mercury, etc., we shall, with each substitution, obtain a new set of relative adhesive powers for each of our solid discs. The most remarkable differences will be found in comparing the adhesion of mer-

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cury to iron with that to such metals as lead, tin, copper, etc.

Similar variations occur in the power of adhesion of the different films of which paints and varnishes may be composed, and it must be understood that in painting or varnishing a metallic surface, it is the adhesive force, pure and simple, that we have to depend upon. In painting wood or other porous material, the adhesion is aided by the fact that the paint penetrates the pores to a greater or lesser extent, and these extensions inward form minute rootlets by which the film is the more firmly held. If the film swells in drying, as in the case of the lineoleine, these roots become firmly wedged, and the paint is almost irremovable.

The practical question before us now assumes a definable shape. It becomes: What available film has the most complete continuity, or least porosity, and the strongest adhesion to iron, and is at the same time insoluble and impenetrable by the vapors and gases of the atmosphere? Here is a large and fruitful field for investigation, and one which has never been systematically tilled. We have only the random results of isolated, conflicting, and ill-recorded experience to guide us.

If I may venture to express an opinion founded on my own observation, which I do with much diffidence on account of its limited and desultory character, I should say that pitchy or bituminous films are especially effective as regards their adhesion to iron. Thus a solution of asphalt or pitch in petroleum or turpentine, leaves a strongly adherent film on drying. It is also very effective as regards its continuity, on account of its manner of drying. Instead of forming a hard and brittle scaly film, like most of the gum resins, the pitch film retains a certain degree of plasticity, which effectually prevents any cracking, and permits a yielding with the contraction and expansion of the iron. If the iron is at all rusty it penetrates the spongy surface of oxide and envelops the rust particles very effectively, holding them together and enlisting their services to form a portion of its paint body. Such a solution of pitch or asphalt may be regarded as something between a paint and a varnish, the pitch or asphalt being a resinous substance, and therefore by its solution forming a varnish; but it is not a pure resin, for it contains, and is colored by, minute solid particles of carbon, and these, of course, when diffused through the solution, correspond to the body of a paint.

Against these advantages there is one serious objection to a mere solution of pitch. It is to a certain extent soluble in water, and thus, when exposed to rain, the bituminous film is gradually washed away. This, however, may be remedied by mixing the solution of bitumen with linseed oil, or with a thin paint made by grinding red or white lead in linseed oil. I have tried this; I find it stand very well, and the experiment may easily be repeated by mixing about two parts of Brunswick black with one of ordinary white, red, or stone-colored paint, the body of which is composed of red or white lead, or litharge. Red lead is the best if well ground in. There are many kinds of bitumen that may be used, such as natural mineral asphalt, pine pitch, and artificial asphalt. There are two distinct varieties of the latter, differing materially in their properties. The first and most common is that which is left when the dead oil, etc., are distilled from common gas-tar; the second, the residue which is left when the spirit, lamp oil, lubricating oil, and solid paraffine are incompletely distilled from petroleum, or from the crude oil obtained by the distillation of cannel coal or bituminous shale. It is this which I recommend. It is easily obtained, and may be supplied in abundance from the neighborhood of Bathgate by the Scotch manufacturers of mineral oil. In order to obtain it in suitable condition for this purpose, the crude oil must be distilled before treatment with acid, and the final distillation stopped before the coking point is reached. By this means a hard bright pitch is obtained which contains a considerable body of carbon, and which is soluble in the unrefined or "once run" paraffine spirit, which itself is a mere drug in the market, and may be supplied at a very low price.

When I was engaged in distilling cannel at Leeswood, in Flintshire, I prepared a quantity of such paint, and used it very successfully for the preservation of both iron and wood. For such purposes as painting the hinges of cucumber frames, the hoops of water barrels, etc., I used it mixed with only a little boiled linseed oil, and without any further body than the pitch contains. When this sort of bitumen, which, for distinction sake, I will call paraffine pitch, is obtainable, no further admix-

ture than about one-half or one-third of its bulk of boiled oil to the solution in spirit is required.

About twelve months ago I was consulted respecting the means of cleaning and preserving a collection of very choice specimens of ornamental mediæval iron work intended for presentation to a provincial technological museum. They had been somewhat neglected and were already rusted. The problem to be solved was, to remove the rust without damaging the surface, and to prevent further corrosion without destroying the metallic tone of the surface or obliterating the sharpness of the fine ornamental work. The rust might have been at once removed by oxalic acid, but this and all other acids penetrate iron to a certain depth, and afterwards set up a new corrosion, however carefully they may be wiped or washed away. Therefore the use of any acid would have been ruinous. Painting over the surface in the ordinary way would have been downright Vandalism, worse than the church warden's mode of cleaning cathedral stone-work by whitewashing it. Ordinary oiling had been tried, but, though preferable to either of these, was not satisfactory. What, then, was to be done?

I obtained from a friend in Flintshire a sample of "once run" mineral oil, *i. e.*, paraffine oil that had been redistilled from the crude oil, but not yet washed with sulphuric acid. This oil contains sufficient free carbon to stain it with a brown tinge, but the particles of this carbon are so infinitesimally fine that their solidity is questionable—they may be regarded as carbon in actual or semi-solution.

This was sent to the gentleman, an amateur artist, who had charge of the specimens, with instructions that it should be first brushed smartly over the surface of the iron until all the rust disappeared, then wiped off and a second brushing applied lightly, and the surface left slightly and uniformly wetted with the oil. These instructions were ably carried out, and the result is reported to be very satisfactory. The rust was removed without violence, the rusted parts regained their natural color when wetted with the oil, and retained it after the oil dried. As the mineral oil is slowly volatile, this drying took place gradually, and an imperceptible film, due to the semi-dissolved carbon, remained behind, and protected the iron from further oxidation without in any degree damaging the tone of its surface. It will, of course, be understood that so delicate a film as this is only fitted for defending the iron from that degree of corrosion to which such carefully preserved specimens are liable. It has the advantage of being very easily applied, and may be repeated with any degree of frequency without damage, as each fresh brushing removes the previous film, as well as any rust or dirt that have subsequently invaded the surface.

Before leaving the paints and varnishes, a few words are due to a very humble and vulgar, but by no means uninteresting mode of protecting iron surfaces, viz., the housemaid's device of "black leading." In these days of general diffusion of chemical knowledge, it is scarcely necessary to state that the "black lead" or "plumbago" of commerce is not lead at all, nor any compound of lead, that it includes no lead whatever in its composition. Neither is it a carburet of iron, as is sometimes stated. It is simply carbon; pure plumbago is pure carbon, impure plumbago is impure carbon. Its proper name is graphite, *i. e.*, writing-stone. I may venture to describe it as the softest of all true solids, and have often pondered wonderingly upon the apparently unnoticed, but very curious chemico-mechanical paradox, that the hardest and softest of all the solids existing upon this earth are, chemically speaking, the same substance; graphite and the diamond being both carbon.

It is this wonderful softness, combined with persistent solidity, that enables us to smear it over any other solid surface, and thus obtain a *solid paint*, all body and no medium. For the class of castings to which it is commonly applied, where its application can be readily repeated, and where it is not exposed to the direct action of water, it is unrivalled as a protecting film to iron. Its chemical action, so far as it does act when cold, is reducing or anti-oxidizing. Its color and tone are so similar to iron that Mr. Ruskin himself could scarcely make any æsthetic objections to its use, and the film is so marvellously thin that it obliterates nothing. I have never met with any attempt to estimate the thickness of a well-brushed film of graphite, but I suspect that if a hundred strata of such films could be piled in actual contact with each other, their combined thickness would fall short of that of the thinnest gold leaf. I base this esti-

mate upon what I have observed in using it for purposes of electro-deposition. The chemist, therefore, can give but little aid to the housemaid in this matter, he can only explain and admire her practical discovery.

The application of protective films by means of fusion, next claims attention. Tinning, and the process to which the absurd name of "galvanizing" has been applied, are the most prominent of these. The principle and practice of the mode of application is the same in both, though the material of the protecting agent is different, zinc being used in the place of tin for the latter process.

In both cases the iron surface is made chemically clean. This is effected by the combined action of mechanical scrubbing and chemical "pickle." The pickle used is hydrochloric acid for galvanizing, and the same with or without a second pickle of sulphuric acid for tinning. The iron thus cleaned is either dipped in a bath of melted tin or zinc, or the melted metal is brushed over it. The dipping is the best, and is used where applicable, care being taken to brush or drain off the excess of adherent fused zinc or tin. It would be out of place here to describe the many precautions necessary to conduct these processes effectively and economically. A considerable amount of skill is demanded, especially in tinning.

This demand for skill, as well as the effectiveness of the protection afforded to the iron, depends on the fact that the tin or zinc is not merely painted over the surface of the iron, but that an actual alloy or amalgam is formed, which extends to some depth below the surface. This is shown by placing a thick piece of iron in a tinning or galvanizing bath, leaving it there for some time, and then breaking or cutting it through. The fracture or section shows that the zinc or tin has penetrated to a measurable depth below the surface, and this depth increases with the time of immersion; thus it is very easy to tin or galvanize a piece of iron completely throughout. Such a piece, on being filed or otherwise worked, presents all the appearance and properties of a true alloy.

In the ordinary course of tinning and galvanizing, the cost of the tin and zinc, especially the former, being considerable, the iron is only immersed sufficiently to insure a complete surface covering, with as little penetration or internal alloying as possible. This fact seriously limits the value of this mode of protecting iron. As we all know, both tinned and galvanized vessels used for containing water begin to rust after a certain length of time, and as the skill of the tinner in economizing material increases, the durability of his work diminishes.

I think that some of our enterprising manufacturers would do well to consider whether it would pay to bring out a new class of tinned and galvanized goods, the tin or zinc of which should be guaranteed to have penetrated bodily through the iron. For many purposes this would be very desirable. Such an alloy would be almost imperishable. As zinc is so much cheaper than tin, and appears to penetrate iron more readily, it is in the direction of galvanizing that this suggestion might be more readily carried out.

The influence of such a soaking of iron and steel with a foreign metal upon its tenacity suggests a very interesting subject for investigation. Is the metal of inferior tenacity so alloyed or combined with the more tenacious iron as to form a compound of intermediate tenacity? Or does the penetrating metal merely soak itself into the pores of the iron or steel, and thus solder together the fibres, crystals or granules, and increase their tenacity? These are fair questions, and worthy of experimental reply.

The protective effectiveness of tinning and galvanizing is unquestionable, but their applications are necessarily limited to small ironwork and utensils. Structural iron can receive but little aid from them. Another limitation is due to the fact that iron of a very superior quality and unblemished surface is required. For tin plates, charcoal iron is commonly used, and even this is subject to failure from the accidental presence of cinder on the surface of the plate. All plates and sheets rolled from puddled iron are subject to this defect, however great may be the care that is used in their manufacture.

There is another mode of protecting iron, viz., by coating it with lead by means similar to those used in tinning and galvanizing. Such leaded iron is utterly unfit to supersede tin plate for culinary utensils, as all soluble compounds of lead are poisonous, and are the most treacherous of poisons, as they act by gradual accumulation. The danger is increased by the fact that acetic acid or vinegar, dissolves lead so readily,

and this acid may be formed accidentally by the fermentation of substances commonly used for food.

For many purposes, such as roofing, spouting, etc., wherever zinc is commonly used as a substitute for sheet lead, this leaded sheet iron may be very useful, and I think deserves more attention than it has yet received. I used it successfully about eight years ago at Leeswood, in Flintshire, for the construction of condensers attached to retorts, in which cannel and shale were distilled for their liquid and solid hydrocarbons. These condensers were upright cylinders standing out in the open air, and cooling by radiation.

Many attempts have been made to protect iron by electro or chemical deposition of copper and its alloys. When electro-depositing was a new invention, several patents were secured for the same idea in its crudest form—viz., the precipitation of copper on iron from acid solutions. All these have utterly failed; the copper peels off, leaving a surface of iron far more corroded than if no attempt at protection had been made.

Some interesting investigations recently made by Mr. W. H. Johnson, of Manchester, on "The Influence of Acids upon Iron and Steel," afford a clear explanation of this. He finds that acids not merely attack the surface of iron, but rapidly penetrate it, and, like the tin and zinc above referred to, can be detected within the iron when a fracture is made. He finds that acids which have thus penetrated, not only continue their corrosive action, but, aided doubtless by the hydrogen evolved and occluded, they seriously diminish the tenacity of both iron and steel.

All who have practically investigated this subject of coppering and brassing iron agree in concluding that if the liquid in which the copper or alloy is dissolved is of itself capable of acting corrosively on the surface of iron, no reliable adhesion of the precipitated copper or brass is possible. By using neutral or alkaline solutions, such as those in cyanide of potassium, an adherent film may be obtained; but even this is not satisfactory, the copper, especially when moderately thick, being very liable to "buckling." This tendency is, I suspect, in a great measure due to the unequal expansion of copper and iron. When raised from 32 to 212 deg. Fah., copper increases in bulk $\frac{1}{104}$, or in length $\frac{1}{582}$, while iron increases only $\frac{1}{787}$ or $\frac{1}{846}$, or, otherwise stated, the expansion of copper when heated, and its contraction in cooling, is nearly one-and-a-half times greater than that of iron. This is a very serious difference, and its practical operation must be the exertion of a continual tearing strain between the two adherent surfaces. I have tested the adhesion of many specimens of such coppered iron by directing the point of a blowpipe flame against a portion of its surface, or, what amounts to nearly the same, by burnishing a portion of the copper surface. In either case an excessive expansion of the copper was produced, and a blister of the copper film was the result. These, of course, are very severe tests, especially the burnishing, which leaves a permanent blister.

Another defect arises from the porosity of such deposits. Although the pores may be invisible to the naked eye, they nevertheless usually exist, and are of sufficient magnitude to admit atmospheric agents, which act upon the iron surface with an energy which is intensified by the voltaic induction due to the electro-negative copper.

These defects have been to some extent remedied by first tinning or zincking the iron and then depositing the copper on the alloyed surface, but the additional expense of this process limits very seriously its applicability, and leaves large structural iron altogether out in the cold.

I must not conclude without some discussion of the merits of enamelling, even though its applicability is as obviously limited. If mere unchecked theorizing were permissible on such subjects, it might be assumed that this a really perfect protective process, the enamel itself being practically imperishable, in reference to corrosive atmospheric agency, and the iron basis affording to the porcelain surface just that tenacious core which its own brittleness demands. But here again inequality of expansion and porosity seriously limit the value of this theoretically beautiful process. The co-efficient of expansion of the vitreous compounds used for enamelling is about $\frac{1}{1000}$, against the $\frac{1}{846}$ of iron, and the brittleness of the enamel renders fatal even a very small difference of expansion or contraction. This is shown in the ruin that comes upon those apparently perfect and beautiful devices, the enamelled frying-pans, saucepans, etc. They chip and scale most vexatiously.

While I was engaged as the teacher of chemistry and its practical applications in

the Birmingham and Midland Institute, an eminent Birmingham firm in the hollow-ware trade consulted me in reference to an improved process of enamelling that was offered for their adoption. The inventor was hardy enough to suppose that it might be applied to the manufacture of evaporating basins and other vessels, in which acids, etc., were to be heated. I devised a simple test which proved quite effectual, and which I venture to recommend for general use in such cases. Some evaporating dishes were made, and I immersed these in a strong solution of sulphate of copper, leaving them there about twenty-four hours. The result was very disagreeable; a large number of small copper warts were dotted on the surface of the enamel, and were especially abundant on the edges of the dishes at the junction between the blue outside and white inside coating of enamel. Mere immersion in acid showed nothing unless continued for several days; but the deposition of copper in the minutest pores, and its outward cauliflower-like expansion, displayed at once those defects, which would have become more vexatiously and mischievously apparent in the course of time had large vessels been made and practically used.

If any enamel stands this test, I think it might be safely warranted for ornamental and other purposes, where the enamelled articles are not exposed to great fluctuations of temperature, such as sign-plates, etc. I have not thus tested any of those which have been lately introduced.

A perfect, or at least satisfactory, and generally applicable method of preserving iron, has yet to be invented. I do not think that the problem is by any means insuperable, for the principle upon which its solution must be based can be clearly stated, and this is an important step towards effecting it. We require something which may be applied easily over large or small surfaces like a paint varnish or lacquer; but it must not be a paint, nor a varnish, nor a lacquer; it must be no mere heterogeneous film holding on by mere mechanical surface adhesion; it must be chemically attached to the iron, as their sulphide and sulphate films are attached to bronze and lead.

What I have already explained respecting the protective action of the compounds of iron with phosphorus, and with silicon or silica, affords fair indication of the direction of research. The ordinary enamels are vitreous compounds of foreign metals fused over the surface of the iron; what we require is to glaze the iron by vitrifying *its own surface*. The Protean solubilities of silicic and phosphoric acids obviously suggest the possibility of doing this without having recourse to fusion at high temperatures. Such a film of iron-glass upon iron would not deface or materially alter the natural appearance or tone of the metal. It would satisfy æsthetic as well as chemical requirements.

The unquestionable importance of fulfilling these desiderata, and a belief in the possibility of doing so, are my main reasons for having thus examined in detail the merits and demerits of the ordinary expedients for protecting iron surfaces, and the elements of the problem which still remain unsolved.

THE FACTOR OF SAFETY IN ENGINEERING STRUCTURES.

By RICHARD H. BUEL.

From "The Iron Age."

Comparatively few engineers have the time or means to conduct thorough experiments on the strength of the materials which they are called upon to use, and in designing work they are generally obliged to accept the results of previous experiments. Fortunately, however, the ultimate strength of most of the materials in common use has been quite accurately determined, for the various strains to which they are subjected —and the engineer has only to decide how much of this ultimate strength he will use for a working load, or what factor of safety he will employ, the factor of safety being the quotient arising from dividing the ultimate strength by the working load.

In choosing this factor, there are several things to be considered—not only the kind of strains, whether tensile, compressive, transverse, torsional, or shearing, that will act upon the material, but also how these strains are to be applied, whether gradually, or all at once, after the manner of a blow. Other matters affecting the choice of a

factor of safety will be mentioned further on. It is easy to see that the effect of a quiescent load upon a structure will be quite different from that of the same load suddenly applied. Suppose, for instance, that a force P is gradually applied to a bar, increasing its length by an amount S. The force commences to act with an intensity of nothing, increasing by slight degrees to P, so that the mean pressure exerted during the elongation is $P \div 2$, and the work of stretching the bar, called the work of resilience, may be represented by the expression $(P \times S) \div 2$. If this same force P is suddenly applied, it will act during the elongation with a mean pressure P, twice as great as the former mean pressure—and if, in the first case, the bar is stretched up to its elastic limit, under the latter conditions a permanent set will be produced, or the bar will be broken. This is an experiment that can be performed by any one, using a spiral spring, and applying a weight to it in the two ways previously mentioned. It would appear from this, that in the case of structures which are to be subjected to the action of impulsive forces, not more than one-half of the ultimate strength can be used for a working load. It seems probable that forces do not generally act in this manner in ordinary structures. In the case of railway bridges and tracks, which are required to sustain a rolling load, both theory and experiment show that the force is more injurious to the material than if it were gradually applied, and that the effect is somewhere between that produced by quiescent and sudden loads, depending upon the speed of the moving train.

Mention has been made of the elastic limit, or the point at which a permanent set occurs, after the material is elongated, compressed, bent or twisted, and it was formerly supposed that when a set was produced, the value of the material for resisting strains was destroyed. Subsequent experiments have shown, however, that a material may take a set without having its strength impaired, and the limiting strain is that which does not increase the set, if repeatedly applied. The weight that will produce this limiting strain is called the proof strength of the material; and as this must never be exceeded in practice, it is evident that the engineer is interested in knowing the proof rather than the ultimate strength of the materials which he is to use. Experiments in regard to the ultimate strength of materials have been more extended than those relating to the proof loads, and hence the constants for the latter cannot be given with so much precision as for the breaking weight. From such experiments as have been made, however, many valuable conclusions have been derived, and it may be well to devote some little space to their consideration.

In regard to tensile strength, the following table gives average values in a few cases:

Tensile strength in pounds per square inch of cross section. (*Strain applied gradually.*)

Material.	Ultimate Strength.	Proof Strength.
Cast Iron	16,500	8,250
Wrought Iron (bar)	45,000	22,500
Wrought Iron (boiler plate)	50,000	25,000
Pittsburgh Steel (plate)	95,000	42,500
Bessemer Steel	99,000	44,500
Black Diamond Steel (bar)	120,700	60,350

These materials, when subjected to the action of sudden strains, give varying results—some of the strongest materials being broken by a blow which does not injure the weaker ones. This is because the elasticity of a material frequently varies inversely as its strength, so that the stronger grades are not so well able to resist shocks as inferior varieties. The following table, token from Trautwine's "Engineer's Pocket Book," to which valuable work the writer is indebted for many of the figures used in this article, will illustrate this fact:

Ultimate tensile strength in pounds per square inch and elongation in inches, before breaking.

(Note.—The specimens tested were steel bars of different grades, made from pure Swedish iron, and each bar was turned down to a diameter of 1 in., for a length of 14 in.)

Specimen.	Per cent. of Carbon.	Breaking Weight.	Elongation in inches.
No. 1	.53	68,100	1.37
No. 2	.43	76,160	1.37
No. 3	.48	84,000	1.25
No. 4	.53	95,200	1.12
No 5	.58	92,960	0.81
No. 6	.63	100,800	1.00
No. 7	.74	101,920	0.69
No. 8	.84	123,200	1.12
No. 9	1.00	134,400	1.00
No. 10	1.25	154,560	0.62

It appears from the foregoing remarks that the proof strength of metals used for structures, in reference to tensile strains gradually applied, has an average value equal to one-half the breaking weight, this value varying with the quality of the material. As many structures are exposed to strains acting somewhat in the nature of blows, not more than half the proof strength should be used as a working load. This fact is recognized by reputable engineers,

who, in designing iron bridges, proportion the parts composed of wrought iron to bear a maximum tensile strain of from 10,000 to 12,000 lbs. per sq. in., and many consider that 8,000 lbs. per sq. in. should be the extreme limit for the working load, on account of some other facts in regard to the strength of materials, which will be briefly considered.

The constants used by the engineer in his calculations are generally obtained by experiments upon small pieces of the materials. Now, it is well known that increase of strength does not always follow in direct proportion to increase of size. A large wooden beam, for instance, is more liable than a small one to be weakened by knots and other imperfections, and on account of the difficulty of securing equal cooling in making large castings, large cast-iron beams are frequently weaker in proportion to their size than small ones. It may be mentioned, in this connection, that Mr. Hodkinson found it necessary to make corrections in his rules for the strength of cast iron pillars, after experimenting upon pillars of larger size.

Structures exposed to the weather are subjected to great variations of temperature, and when metals are cooled, although they resist quiescent loads quite as well as before, they are more easily injured by sudden shocks, such as are caused by rolling loads.

It is commonly recommended in treatises on the strength of materials, that from $\frac{1}{4}$ to $\frac{1}{6}$ of the ultimate strength of the materials should be taken for a working load; but it would seem that the proof strength is really the limit to be considered. This can be illustrated again by a reference to the resistance of materials to transverse strain. The application of a load to a beam causes a deflection, and, if the proof load is exceeded, the material can no longer be regarded as safe. From the results of experiments on the deflection of beams, the following table is compiled.

Average values of ultimate and proof strength in pounds, of beams one inch square and one foot in length between supports, when supported at both ends and loaded in the middle, the load being gradually applied.

Material.	Ultimate Strength.	Proof Load.
Cast Iron	2,000	800
Wrought Iron	2,400	1,000
Steel	6,000	5,000
White Pine	450	150
Oak	600	200

These, it must be remembered, are average values, the same variations being observed in different qualities of the same material when suddenly strained, as previously remarked in the case of tensile strength, so that really the proof strength is the only safe figure from which the engineer can deduce the factor of safety. Average values of these factors, so that the load shall equal the proof strength, are given below:

	FACTOR OF SAFETY.	
Material.	Load gradually applied.	Impulsive Load.
Cast Iron	2.5	5.
Wrought Iron	2.4	4.8
Steel	1.2	2.4
White Pine	3.	6.
Oak	3.	6.

It will be seen that the proof loads vary with the different materials, whence the factors of safety for the working loads will also vary, if they are taken with reference to the ultimate strength of the materials, while, if calculated with respect to the proof loads, they will be the same in every case. This will be rendered clear by the accompanying table, which also contains other matters of interest. (See Table A.)

The breaking weight W, W′, W″, in the above table, are to be calculated for any particular case by the formulas in general use, using for constants the figures given in tables of the transverse strength of materials. The deflections, D, D′, D″, can be calculated or determined experimentally for a beam supported at both ends and loaded in the middle, when the deflections for other distribution of the load are given at once from the table. The deflections d, d', d'', are determined in the same way for any loads less than the proof, and the table shows the corresponding deflections when this same load is differently applied. By observing the relations given in the table, the load required to produce any deflections within that produced by the proof load, can readily be calculated. The safe load assumed in the table is one that is approved by experiment, though somewhat smaller than is often allowed. The following table is calculated for this load, or with a factor of safety of one-third the proof strength. (See Table B.)

Before concluding, a few remarks will be made about the factor of safety for the iron used in the construction of steam boilers. The most reliable authorities on this subject state that a factor of 6 in relation to ultimate strength is the least allowable,

TABLE A.

Rectangular Beams, loaded so that the deflection shall not exceed one-third of that caused by the proof load.

Material.	Distribution of Load.	Breaking Weight.	Proof Load.	Deflection under Proof Load.	Deflection under the same Load.	Assumed Safe Deflection.	Load that will produce Safe Deflection.	Factor of Safety.	
								In reference to ultimate Strength.	In reference to proof Strength.
Wrought Iron.	Supported at both ends, and loaded in the middle	W	0.417 W	D	d	0.333 D	0.138 W	7 2	3
	Supported at both ends, and uniformly loaded	2 W	0.833 W	1.25 D	0.625 d	0.417 D	0.278 W		
	Fixed at one end, and uniformly loaded	0.5 W	0.208 W	3 D	6 d	D	0.069 W		
	Fixed at one end, and loaded at the other	0.25 W	0.104 W	4 D	16 d	1.333 D	0.034 W		
Cast Iron.	Supported at both ends, and loaded in the middle	W′	0.4 W′	D′	d′	0.333 D′	0.133 W′	7.5	3
	Supported at both ends, and uniformly loaded	2 W′	0.8 W′	1.25 D′	0.625 d′	0.417 D′	0.267 W′		
	Fixed at one end, and uniformly loaded	0.5 W′	0.2 W′	3 D′	6 d′	D′	0.067 W′		
	Fixed at one end, and loaded at the other	0.25 W′	0.1 W′	4 D′	16 d′	1.333 D′	0.033 W′		
Timber	Supported at both ends, and loaded in the middle	W″	0.333 W″	D″	d″	0.333 D″	0.111 W″	9	3
	Supported at both ends, and uniformly loaded	2 W″	0.667 W″	1 25 D″	0.625 d″	0.417 D″	0.222 W″		
	Fixed at one end, and uniformly loaded	0.5 W″	0.167 W′	3 D″	6 d″	D″	0.056 W″		
	Fixed at one end, and loaded at the other	0.25 W″	0.083 W″	4 D″	16 d″	1.333 D″	0.028 W″		

TABLE B.

Safe Loads, in Pounds, for Rectangular Beams whose length between supports is l feet; breadth, b inches; depth, d inches; and unsupported weight of the beam, B *pounds.*

Distribution of Load.	Wrought Iron.	Cast Iron.	White Pine.	Oak.
Suported at both ends, and loaded in the middle	$333 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$267 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$50 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$67 \times \frac{b \times d^2}{l} - \frac{B}{2}$
Supported at both ends, and uniformly loaded	$667 \times \frac{b \times d^2}{l} - B$	$533 \times \frac{b \times d^2}{l} - B$	$100 \times \frac{b \times d^2}{l} - B$	$133 \times \frac{b \times d^2}{l} - B$
Fixed at one end, and uniformly loaded	$167 \times \frac{b \times d^2}{l} - B$	$133 \times \frac{b \times d^2}{l} - B$	$25 \times \frac{b \times d^2}{l} - B$	$33 \times \frac{b \times d^2}{l} - B$
Fixed at one end, and loaded at the other	$83 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$67 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$13 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$17 \times \frac{b \times d^2}{l} - \frac{B}{2}$

while it is more desirable to use a factor of 8. The experiments of Sir William Fairbairn have shown that the strength of a single riveted joint has but 56 per cent. of the strength of the sheet, and that a double riveted joint, properly constructed, has 70 per cent. The average tensile strength of boiler plate, as given above, is 50,000 lbs. per sq. in., and much is used that falls below this figure. This will give the ultimate strength of the riveted joint as follows:

Double riveted	35,000
Single "	28,000

Hence the greatest allowable working load should be:

Double riveted	5,833
Single "	4,667

And the best authorities recommend that the working load should not exceed:

In boilers with double riveted joints	4,375
" " " single	3,500

A committee appointed by the Franklin Institute, of Philadelphia, to determine a safe value for the strain upon steam boilers, have recently reported to that body. They assume the ultimate tensile strength of a single riveted joint to be 34,000 lbs. per sq. in., and recommend that 6,000 lbs. per sq. in. be taken for the working strain. If the foregoing data are correct, this allows a factor of safety of 28,000÷6,000=4.67, far below what is generally assumed to be a safe limit. It may well be doubted whether this influential body has not committed a grave error in pronouncing this opinion.

THE MANUFACTURE OF FIRE-CLAY GOODS.

From "The Builder."

Manufactures in fire-clay, comprising, as they do, many articles other than those which must necessarily possess fire-resisting properties, are rising in importance to an extent not generally recognized; some idea of which may be formed from the fact of fire-clay goods being used for the lining of furnaces and domestic fireplaces, the drainage of towns, and the ornamentation of public buildings.

Fire-clay is found in various parts of Great Britain; the most noted seams occurring at Dinas, in Wales; Kilmarnock and Glenboig, in Scotland; and Stourbridge, Plympton, Newcastle, Burton-on-Trent, Poole, Hedgerley, and Wortley, in England. The celebrated Dinas rock, when made into bricks, is almost pure silica; but generally the proportions are 59 to 84 per cent. of silica, 36 to 8 per cent. of alumina, with small quantities of peroxide of iron, lime, magnesia, potash, and soda. Generally speaking, the more the first and less the five last-named substances preponderate, the greater will be the value of the clay they compose.

The occurrence of fire-clay, and the strata with which it is associated, vary in almost every case; it is usually found in the coal-measures, immediately underneath the coal; and, as space precludes, and similar conditions render unnecessary a description of its position and mode of working in every locality, a brief account of what is done in the Wortley district (near Leeds) will be given as sufficient for the purposes of this article.

In a district, remarkable from a geological point of view; broken up by faults in the strata into areas; separated, as far as the mining engineer is concerned, although continuous to the farmer; averaging rarely as much as 100 acres each, occurs a seam of coal from 8 in. to 18 in. thick, and from 10 yards to 120 yards below the surface, known as the "Better Bed," and remarkable for its freedom from sulphur, and consequent value for iron smelting. Underneath this bed of coal occurs a silicious rock of bluish-grey color, containing impressions of plants, sigillaria, etc. When the depth is not more than about 80 yards below the surface, it is of a shaly nature, and falls to pieces after being exposed to the atmosphere, and is the fire-clay proper; but, as the depth increases, this rock becomes more of a stony nature, and unfit for manufacturing purposes. [The word "rock" is used in its geological sense, meaning any layer of material, soft or stony.] The thickness of the fire-clay is about 2 ft., and it is obtained along with, and in a similar manner to, the coal.

The clay being raised to the surface and conveyed to the works, the process of manufacture commences by (1) grinding, separating, and mixing; (2) moulding and drying; and (3) burning and (when re-

quired) glazing. The clay being "weathered," or disintegrated by atmospheric action, it is thrown into a flat-bottomed circular revolving pan, about 9 ft. diameter, having two stationary rollers about 5 ft. diameter, 15 in. wide, and each 2½ or 3 tons weight; by these the clay is crushed to a powder sufficiently fine to pass through gratings, ½ in. wide, in the pan bottom. After leaving the pan, the clay—now in a state of somewhat dry powder—is raised by an elevator, consisting of sheet-iron cans attached to an endless band, to the top of a series of screens, varying in degree of fineness, by which the clay is separated accordingly; and any coarse lumps that will not pass the screens are returned to the grinding-pan.

The men who work near the screens have to breathe an atmosphere in which fine dust floats to an unpleasant extent. A plan is about to be tried at one of the principal works in the Leeds district to separate the clay by a fan in a long chamber, the air being filtered by having to escape through sheets of canvas at the end opposite to which the fan is placed; if this succeeds, the finest dust, which is the most valuable, will be available for the best class of ornamental tiles, etc., and the grinding-house a more tolerable workshop than it is at present.

The clay is usually separated into four degrees of fineness, according to the work it is required for; and this being done, it is thrown or mechanically conveyed into a pan similar to that described for grinding, but with a solid bottom, and rollers about half the weight; with the addition of a certain quantity of water, it is mixed into a paste in a short time, and so thoroughly that a pastry cook could not find fault with, but might wish for a similar apparatus to reduce the labor now necessary to provide for the demands of our juveniles for tarts. A scoop, which the attendant soon learns to handle dexterously, empties the mixing-pan while revolving, and deposits the pasty clay into a barrow, or small four-wheeled wagon, in which it is conveyed to another department for further operations.

When the clay has to be used in large masses, such as retorts for gas works, large drain pipes, etc., powdered fire-bricks or fire-clay goods that may have cracked while burning, are added to the clay when being mixed; and for the crucibles used by brass founders and others, plumbago or carbon in some other form is added. Various mixtures are employed; for instance, the best terra-cotta is produced by certain proportions of fire-clay mixed with Dorsetshire plastic clay.

As the treatment of the clay differs for the various articles made, it will be necessary to describe the moulding and burning for each kind. Premising that the clay is delivered to the workmen in a plastic condition, the manufactures may be said to consist of common fire-bricks, retorts for gas works, sanitary tubes, glazed and enamelled bricks and terra-cotta.

Fire-bricks are made in a large shed, in which tables are placed; at each table a man is stationed and kept supplied with clay. The moulds consist of what may be called a rectangular box, without top or bottom; the clay is first kneaded by the brickmaker to a shape roughly approximating to, and then pressed into the mould. [Here an intending visitor to the brickworks may be cautioned against going too near the table (if his coat is a good one), as brickmakers take a cruel pleasure in bespattering respectable clothing.] Two boys are required to carry away the bricks made by one man; and they are then laid upon the floor, heated by steam, or the products of combustion from fires placed at one end that pass under the floor on their way to the chimney; by these means the bricks are dried so as to bear piling in the kiln. As an illustration of the necessity of employing a material that is a good conductor of heat to form the floors of drying-sheds, it may be mentioned that a floor made of cast-iron plates will cost nearly three times as much as a fire-brick floor; but will only require about two-fifths of the fuel to dry the same quantity of bricks; the saving in coal being 56 per cent. in favor of the iron floor.* The bricks are now ready for burning. The kilns considered best are rectangular, about 40 ft. long, 20 ft. wide (outside), and 8 ft. or 10 ft. high inside; the top is arched over, and in this arch are small openings at intervals for the whole length, to allow steam and products of combustion, after having circulated among the bricks, to escape. The fireplaces are on both sides of the kilns; and according to the number on one side, they are designated "8-holed" or "10-holed" kilns.

Retorts are round, oval, and D shaped

* From experiments by the writer.

about 3 in. thick, 4 ft. to 10 ft. long, and are built up in annular wood moulds. The clay, being used in large masses, must possess a certain degree of porosity to insure thorough burning and non-liability to crack; this is secured by adding to the fire-clay when in the mixing pan, fire-clay material that has been previously burnt, and afterwards powdered, as before mentioned (and sometimes sawdust also); so that when the built-up retort is being burnt, the raw clay shrinks, while the "rough stuff" retains its original bulk (sawdust, when used, being consumed), and the finished article left sufficiently porous. The shrinkage of fire-clay is such that any article to be 12 in. long after, must be 13 in. before, being burnt.

Sanitary tubes are made in a machine; the best consisting of a cylinder having an open top, and an annular opening in the loose plate that covers the bottom equal to the transverse section of the pipe it is required to produce. In the cylinder fits a piston, attached to the end of the rod of another piston working in a steam cylinder placed immediately above that for the clay. When a pipe is to be made, the pistons are raised by admitting steam into the lower end of the upper cylinder; the lower piston being then raised some inches above the top of the clay cylinder, so as to allow plastic clay to be thrown in. By admitting steam on the top side of the upper piston, the clay is forced by the lower piston through the annular opening in a manner analogous to the working of a sausage machine, only that a hollow instead of a solid stream issues from the pipe press. The pipes are cut off by a wire to the required length (generally 2½ ft.), and the sockets for small pipes (3 in. to 8 in. diameter) are luted on by hand, although there are machines with a pair of movable dies to form the body of the pipe and its socket at one operation, similar to the larger machines; but little more than half the quantity can be made by the same machine when the sockets are also formed by it. The tubes are set vertically, and dried by heat from steam pipes placed about 6 ft. *above* the floor on which the tubes stand, so as to dry the sockets first; after which they are turned over for the "spigot" (or plain end that fits into the socket of the pipe next to it when laid), to be "fettled." By these machines, tubes can be made with rapidity up to 30 in. diameter, in quantities varying according to size, from 3,000 to 150 per day per machine. Sanitary tubes (and retorts) are set in kilns with their axes vertical, so that the flame can pass both outside and through them. To give the tubes the glaze, which all who have seen a town drain being put in have doubtless noticed, chloride of sodium (common salt) is thrown into the fire; the heat being sufficient to volatilize it, and cause a coating of silicate of soda to be formed on the exposed surfaces of the tubes.

The application of bricks having glazed enamelled faces to the interior of bath-rooms and baths, fishmongers' and other shop walls, the walls of entrances and passages of private houses, lavatories, etc., is another advantage for which those who design buildings, and those who keep them clean, are indebted to the manufacturer. For durability, cleanliness and cheapness combined, these bricks are unrivalled. They are produced in various colors; Venetian and coral reds, black, greens and blues of various shades, grey, drab, buff and white; the tints being stated in the order that they are charged for; red being the most difficult, and white the easiest to obtain perfect.

After being moulded and dried, similar to fire-bricks, they are taken to a powerful screw press, from which they issue perfectly square and smooth on the angles and surfaces. The coloring matter is applied by dipping the bricks into "slip," a felspathic and silicious liquid of the consistency of good cream; they are then laid on shelves in the drying shed until the following day, when the glaze is applied on a similar manner to the "slip." The bricks ordinarily made are "headers," which are glazed in one end only; "stretchers" on one side; "splayed ends," having a triangular piece cut off one corner, and glazed on the three sides formed by what were two in the common brick; and "bull noses," having one corner cut off by a quarter of a circle, and glazed round it and the adjacent side and end. For all colors, excepting white, the bricks have to be burnt after "slipping," and again after glazing; no kind of colored "slip" having yet been discovered that will bear the application of glaze before a preliminary burning. For this class of work the greatest care is necessary in every stage of the process, to avoid chipping the corners or defacing the exposed surfaces before and after burning, to maintain the proper heat in the kilns, and

to see that a first-rate quality of coal is used. Chimney-pots, and terra-cotta wares generally, are made in plaster moulds, the manufacture being more or less complicated, according to the degree of ornamentation; they, and the enamel-colored glazed bricks, have to be burnt in "muffled" kilns —or those in which the flame does not come in contact with the articles being burnt. The good quality of these wares is indicated by a pure and regular color, smooth faces, sharp edges, and a clear ringing sound when struck.

This description of the fire-clay manufacture is necessarily a very general, and, to some extent, an incomplete one. Many modifications are thought to be advisable by some manufacturers, both in machinery and methods of working; but as a brief account of the practice of some of the most eminent firms in the trade, it may be accepted as showing the degree of perfection at present reached; future inventors will, doubtless, increase the facilities for producing articles, the demands for which are now in excess of the supply.

STEAM REGENERATION.

From "The Engineer."

A short time ago, a party of scientific men assembled at Stafford House, by the invitation of the Duke of Sutherland, and became witnesses to one of those pretty little puzzles in natural science which serve to show that our definitions are occasionally somewhat too narrow to comprehend all the facts to which they stand related. To make a body hotter by bringing it in contact with a colder one seems altogether a paradox, unless we include the idea of chemical action. So also, to think of condensing steam by passing it into a liquid hotter than itself seems rather a forlorn hope. When Mr. Spence proposed to apply steam in such a way as to make a liquid boil at a temperature much higher than that of the steam itself, he was told that such a result would be "contrary to the laws of nature." Nevertheless, Mr. Spence was prepared to perform the feat, seeing that he had already accomplished it. So at Stafford House he —or rather his son—boiled water in a flask, and turned the steam into an open glass tumbler containing a certain liquid with a boiling point considerably above that of water. After a few minutes this liquid apparently boiled, and gave off steam which was estimated as equal to a pressure of 30 lbs. on the sq. in. The liquid was simply water with a strong admixture of caustic soda. We have since repeated the experiment, taking care to have the caustic soda thoroughly dissolved before introducing the steam. By this precaution we excluded the effect of the heat which is evolved while the alkali is dissolving. The steam from the flask of boiling water was then introduced, and in a few minutes the temperature of our solution rose to 226 deg. Fahrenheit, where it remained stationary. In this instance the solution was placed in an open-mouthed flask, and the temperature of the rising steam in the neck of the flask was between 215 and 216 deg. There was a good deal of agitation in the liquid, but we can hardly say it was boiling.

During the exhibition of the experiment at Stafford House, the elder Mr. Spence offered an explanation of the phenomenon in the language of the old material theory. He suggested that the caustic alkali had a greater affinity for water than for caloric. Hence the soda arrested the water of the steam, and liberated the accompanying caloric, which accordingly became free to heighten the temperature of the surrounding liquid. Of course, this antiquated philosophy jarred somewhat on the ears of the *savants*, and Colonel Strange intimated that if Mr. Spence was going to work on that line, he would have to fight a battle with all the physicists in Europe. Still, although it was easy to quarrel with the calorific hypothesis, nobody suggested anything better. There was the thermometer, very provokingly sticking fast at some elevated temperature far above the boiling point of water, and nobody seemed any the wiser for it. *Cui bono?* was one question, and in answer to this, Mr. Spence exhibited a diagram showing a method for turning waste steam to profitable account. For some time the audience could not quite understand the diagram, and when they did they refused to believe in it. Mr. Crampton was zealous in his questioning

and kindly in his suggestions, but held out very little hope that this caustic soda business would lead to any profitable issue. Another authority considered that nothing could excel the simple method of turning the waste steam into the tank from whence the boilers took their supply. The grand problem was to know what Mr. Spence could do with a pound of coal. If he could economically get coal to raise more steam than heretofore, fame and fortune were his.

A cheque, somewhere between £100 and £1,000, would suffice to show what was the state of the case in this respect, and for this further adventure the audience were willing to wait, evidently expecting very little to come of it. Something is due to the acuteness of the elder Mr. Spence in detecting a phenomenon hitherto so little known as to be disbelieved when stated. The younger Mr. Spence has embraced the idea that the peculiar property thus observed may be turned to a practical use, and there is a possibility that he may not prove altogether wrong. The phenomenon has not been entirely unknown in the past, although almost universally overlooked. We have reason to know that Mr. Perkins —celebrated as the apostle of high pressures—many years back made experiments resembling the one to which we have just referred, though with a different material. As the matter has thus been rendered prominent of late, and no satisfactory explanation has been forthcoming, we have thought it worth while to attempt a further investigation of the phenomenon. For this purpose a solution of caustic soda was made, containing 36 per cent. of alkali. The boiling point of this solution was found to be 239 deg. Fahr. A quantity of this solution, equal to 4,420 measured grains, was placed in a glass flask to which were fitted two thermometers, one to indicate the temperature of the alkaline solution, and the other that of the exit steam; a tube for conducting steam from a flask of boiling water dipped into the alkaline solution being immersed to the depth of about 3½ in. The water in this other flask amounted at the outset to 3,500 measured grains. In adjusting the thermometer which was to show the temperature of the exit steam, care was exercised that neither radiation of heat from the alkaline solution nor any splashings from the boiling liquid could reach it so as to affect the readings.

Flame being applied to the flask of water, the temperature rose until the liquid boiled. A lesser degree of heat was applied to the flask containing the solution, so that the temperature of the latter immediately before the steam entered it was 133 deg. With the entrance of the steam the temperature rapidly rose until it reached 233 deg. A higher temperature would doubtless have been obtained had not the condensation of the steam diluted the liquid, and thereby lowered its boiling point. As a matter of fact, the observed temperature of 233 deg. may be taken as the boiling point of the solution as it then existed. The exit steam never rose above 209 deg., which is not a little curious. The experiment lasted about forty minutes, and during the latter part of the time the temperature of the solution sank from 233 deg. to 229 deg., a result doubtless occasioned by the lowering of the boiling point in consequence of the dilution of the liquid by the continued condensation of the steam. After the above lapse of time the boiling was discontinued and the apparatus disconnected. The water remaining in the flask was then found to be 1,750 grains, while the volume of the soda solution had become augmented to 5,750 grains. The quantity of water converted into steam was, therefore, $3500 - 1750 = 1750$ grains, or exactly half. Referring to the alkaline solution, we observe that starting with 4,420 grains, the amount at the end of the experiment was 5,750 grains, showing, therefore, an augmentation of 1,330 grains. Deducting this increment from the total quantity of water evaporated, we get 420 grains. Accordingly we are led to the conclusion that out of 1,750 grains of water converted into steam, no less than 1,330 were imparted to the alkaline solution, while only 420 grains passed off finally as free steam.

The latent heat of steam at the ordinary pressure of the atmosphere is 934; that is to say, every pound of steam condensed to water evolves sufficient heat to raise 934 lbs. of water 1 deg. Fahr. The alkaline solution was raised from 133 to 233, or 100 deg., and was maintained nearly at that temperature throughout the period of forty minutes. As one grain of steam can raise 934 grains of water through 1 deg., so 1,330 grains of steam—the weight condensed in the alkaline solution—are capable of raising 1,242,220 grains of water 1 deg., or 12,422 grains of water 100 deg. As, however, the

specific heat of a solution of potash is less than that of water, the steam in this case will actually do more. Taking the specific heat of water as unity, that of our solution would be 0.931. Hence the steam would raise about 13,000 grains through a range of 100 deg. As the actual quantity of the solution was only 4,420 grains, we see that theoretically the latent heat from the steam would really raise nearly three times the amount of soda solution through the observed range of temperature. The excess of heat shown by theory was in all probability lost by radiation, as during the forty minutes occupied by the experiment no provision was made to prevent the radiation of heat, the flask of alkaline solution being wholly unprotected.

Of course we do not pretend that the foregoing calculation is to be taken as altogether exact. Certain corrections are obviously required; but scrupulous exactness is unnecessary, as we are only seeking for a principle, which is abundantly demonstrated by those results which the most refined analysis would leave untouched. Proceeding with our experimental investigation, the next step consisted in trying the effect of steam on water in which a neutral salt had been dissolved. Thus a saturated solution of common salt was prepared, and the boiling point was found to be 228 deg. Steam passed into this solution raised the temperature as high as 226.5 deg. Finally, an acid was employed, a solution being prepared by mixing one part by measure of sulphuric acid, specific gravity 1.84, with three parts of water. The boiling point of this mixture was 237 deg., and the admission of steam into it raised the temperature to 229 deg. It is singular that in this last experiment the original boiling point of the solution was not more closely approached, the deficiency being decidedly greater than when the other solutions were employed. Taking the three substances used in solution, namely, caustic soda, chloride of sodium, and sulphuric acid, as representatives of alkalies, salts, and acids respectively, and seeing that in each case the same phenomenon occurred, it is a fair inference that any form of matter which would raise the boiling point would give a like result. The idea of an explanation being offered by the fact of caustic soda having an affinity for water, is evidently displaced by these more general results. That steam passing into a solution with a high boiling point is capable of producing a temperature higher than that of the liquid from whence the steam proceeds, is perfectly clear; and this result is evidently due to the latent heat of the steam, which again leads us to the conclusion that, during the latter part of the process, the steam undergoes condensation in a liquid hotter than itself. The solution seems to have the property of absorbing heat until its own boiling point is attained, and thus reaches a temperature higher than that of the steam by which it is heated, a phenomenon which still remains sufficiently paradoxical. Concerning the steam, we observe that it becomes resolved or condensed into the general volume of the solution, and in that state—while literally condensed—is hotter than it was before.

With regard to the utilization of the property to which we have thus referred, the cost of the material seems to be a serious drawback if caustic soda be employed. Common salt, although giving a lower boiling point, might yield a better commercial result. But are there not waste liquids having a boiling point above that of water? The waste steam of a manufactory might be turned into the waste liquid, and the heat intensified so as to become useful.

DECAY AND PRESERVATION OF TELEGRAPH POLES.*

From "Iron."

The earlier telegraphs were all constructed with the very best Baltic timber. The first line erected for commercial purposes, viz., that between Nine Elms and Gosport, upon the London and South Western Railway, in 1844, was built entirely of the best foreign timber. Of Memel we have considerable experience. For over 100 years it has been largely imported into England, and as largely used where strength and durability have been a matter of importance. Memel, Riga, Dantzic, Norway, Swedish, and what is in England known as

*A paper read before the Society of Telegraph Engineers by Mr. Wm. Langdon.

Scotch fir, are all the same species—*pinus sylvestris*. The great difference which exists in the foreign and home-grown wood is simply the result of the difference of climate and soil. The genus is the same.

It was about the year 1851 that native-grown larch (*larix communis*) was first introduced for telegraph poles. This timber, when used for telegraph purposes, is required to possess the natural butt, as much for durability as for strength. Formerly, round poles were usually specified to be not less than 4 in. diameter at the top, and for heavy lines 5 in. Of later years these dimensions have been increased to 5 in. and 6 in. respectively.

When the tree is cut down, all the undigested liquids in course of time evaporate and disperse, provided it is so placed as to enable this so-called "seasoning" to go on; but if they are allowed to remain they putrefy or ferment. There are two kinds of decay, viz., *dry* and *wet rot*. The former is a slow mouldering action, due to the presence of a species of fungus called the *merulius lachrymans*. To this form of decay we are fortunately seldom subject, but in *wet-rot* we find our great enemy. *Wet-rot* is of two kinds, oxidation and disintegration. The first is a species of slow combustion, or "eremacausis;" the latter explains itself. Experience gives the average life of an unprepared telegraph pole as seven years. In many instances, however, this is considerably over the mark.

The mileage of telegraph lines in England, Scotland, Ireland and Wales, may, at the present time, be fairly stated to be not less than 24,000. Take it that one-half of these lines are built of timber protected by some preservative process—there remains 12,000 unprotected. The renewal of these lines at £20 to the mile—a sum no doubt considerably under the actual cost—represents a sum of £240,000. If we can add to the duration of the life of the timber one-half of the average term (say seven years) it means a saving of £120,000 during every such period.

It is well known that the point at which our poles decay is that at which the greatest strength is required, viz., the ground line known as the *wind and water line*. Wood, when not affected with dry-rot, may be said to retain its lasting properties for a prolonged period, under the following conditions:—1. When kept dry. 2. When continually under water. 3. When wholly buried beneath the soil at such a depth as to secure an equable temperature and moisture. It may safely be said that in no case do telegraph poles conform to any one of these conditions.

I have spoken of the decay due to eremacausis or slow combustion, but there is another process of disintegration of a mechanical nature, and it is this process to which the destruction of our poles is mainly due. In this, the tiny particles of moisture held in the outer pores of the wood first become heated, then volatilize, and finally, bursting asunder the delicate fibres by which they are bound, escape into the surrounding air. No sooner has one particle of moisture burst the bonds of its chamber, than it is followed by another and another, each one aiding in the work of disintegration, until its structure is utterly destroyed.

The methods which are adopted for the preservation of timber from the destructive effects of dry and wet rot are of two kinds—the one applied externally and the other internally. The external applications are:

1. *Seasoning*, the natural system of which is well known; the artificial is by means of hot-air chambers. It is also frequently immersed for a long time in salt water, by which process the sap and germs of decay are supposed to be washed out.

2. *Charring and Tarring.* — Charring consists in slightly roasting or carbonizing the surface of the wood, when it is dry, to a distance of 6 ft. or more from the base of the pole. It expels the sap, if any remain, destroys the external ligneous pores of the wood, coating it with a hard shell, checking absorption, and it kills the germs of animal and vegetable life that exist in that portion of the tree. The portion charred and some 3 ft. of the pole above is usually coated with tar while it is hot. When a pole has been not merely charred, but also well tarred about the wind and water line only, we notice that decay is removed to the point above that so treated, at once giving evidence of the good done, and suggesting that, if the whole of that portion of the pole placed underground had been served in a similar manner, the destructive action might have been still further delayed. The bottom of the pole is frequently neither charred nor tarred. It is here that moisture creeps in, and it is from this point that, under the influence of the higher temperature above, it is drawn upwards, until it reaches that part where the pores of the

wood are no longer sealed up. Here it breaks forth, tearing the fibres asunder, disintegrating and destroying the wood in the manner observed. The tops of the poles, if not preserved from moisture, decay. In some countries they merely point the poles and paint them, but in England they are invariably protected with roofs and caps, usually galvanized iron roofs bent and nailed on the top, sloped for the purpose.

3. *Local Applications.*—The general decay of telegraph poles began to develop itself in the year 1855, and local applications to the "wind and water" mark were applied. Gangs were sent about the country removing the ground to a depth of about 2 ft., cutting off the decayed part of the poles, and plastering it above and below the ground line with asphalt, and eventually with cast iron and earthenware cylinders filled with asphalt. Some years since Mr. Preece attempted to stay its ravages by encasing the butt-end of the pole in an earthenware jar, filling up the space between the jar and the pole by a compound of hot tar, lime, and felt. Mr. Haynes, the telegraph superintendent of the Bristol and Exeter Railway, says that about twenty years since the Electric Telegraph Company erected between Yatton and Worle station three miles of wooden poles, fitted with screw iron sockets. Of these no renewals were necessary until last year. He then found that several of the poles had gone badly near the sockets, and others were rotted near the top. Those that were bad at the bottom were several inches below ground.

The internal application of the best known preservative processes is of two kinds:—1. The introduction into the pores of the wood of some salt, which, uniting chemically with the albumen of the sap, is stated to convert it into an insoluble compound. 2. The introduction of some oil, which not only acts as an antiseptic, but renders the woody tissue water-proof. Under the first head several processes have been tried; but the best known are Burnetising, Kyanising, and Boucherising.

Burnetising consists in impregnating the timber when dry with a solution of sulphate of zinc. The original poles on the London and South Western Railway, erected in 1844, were so served, as were others erected on the Midland in 1846. They were in both cases of the best Memel timber. After sixteen years, Mr. Preece reported on these poles as follows:—Of those in sand, 74 out of 97 required spurring; in chalk, 50 out of 112; in gravel, 25 out of 70; in clay, 18 out of 73. All these poles were renewed by the end of 1871.

Kyanising consists in impregnating the timber with a solution of corrosive sublimate (mercuric chloride). In both Kyanising and Burnetising open tanks are filled with the solution with which the timber is required to be charged. The timber is then submerged in it, well fixed down, and allowed to remain soaking until it has absorbed the proper quantity of the solution. On the Cornwall Railway some 400 larch poles, prepared under this process, were erected some seven years since. Mr. Webber, the telegraph superintendent of that line, states they are apparently as sound as ever.

Boucherising consists of impregnating the timber with sulphate of copper. This is effected by applying a solution of this description to the butt-end of the pole under a gentle pressure provided by the weight of the liquid itself, which is usually arranged in tanks at a height of some 50 ft. above the level at which the timber is placed. The lasting properties which this process imparts to timber appear to vary considerably. Mr. Culley has pronounced the system a failure except under special circumstances. In some instances poles which have not been planted more than six years have been removed owing to dry rot. In other cases they have still been found good after standing thirteen or fourteen years. Boucherising has, in spite of its apparently uncertain action, the recommendation that it can be applied in the wood in which the tree grows, thereby probably saving a considerable outlay in carriage; that poles prepared by it can be made use of immediately; in fact, that a tree may be cut down, hauled into the Boucherising yard, subjected to the process, and erected as a telegraph pole in a month, and this with a prospect of its lasting some ten or twelve years.

Attempts have been made to render timber indestructible by supplying the tree with antiseptic salts while growing. The most complete experiments in this direction were made by Mr. Hyett, who not only supplied the living tree with preservative materials, but changed the color of the wood so as to make beech appear a beautiful mahogany, and larch an exquisite rosewood. In this system, about six inches

from the ground a 2 in. auger-hole is bored quite through the centre of the tree, a narrow saw is then introduced, making a horizontal cut right and left of the tree. A clay basin, holding about two gallons, is arranged around the bottom in which the solution was placed. In this way, it is stated, trees became thoroughly impregnated with the required salt.

We now come to the preservation of timber by oil, and under this head we have simply to deal with that system known as *creosoting*. The theory of the application of creosote is that it is not only an antiseptic, but it destroys any vegetable germ which may exist in the timber, and that it renders it impervious to moisture. Its usual mode of application is by placing the poles within a cylinder, which is then made air-tight, and the air exhausted from it. In exhausting the air it is said any moisture held in the wood is also removed. This is very doubtful. However, the air being exhausted, the creosote is then turned in the cylinder, and injected into the wood, under a pressure varying according to the contents of the cylinder. There can be no question that in creosote we have by far the best preservative yet produced. It is cheap, easily applied, and effective. Perhaps no greater recommendation of its efficiency can be offered than the fact that there is now standing, to all appearance as good as when first erected, a line of poles between Farehain and Portsmouth, on the London and South-Western Railway, which was erected in 1848-9. These poles are now five-and-twenty years old, and, when examined a few months since, gave no sign of decay. In 1861 Mr. Preece, reporting upon this form of preservative, states that out of 318 poles examined only two gave signs of decay, and that at the top of the poles. The poles had been standing twelve years.

In creosote we no longer deal with an *absorbent of moisture*, but with something *directly opposed to it*. Hence its power of resisting that action which has been described as destructive to the pole, and hence the durability of creosote over all other descriptions of prepared timber. Let the timber be dry when the creosote is applied, and let it be applied under proper pressure; the result need not be questioned. But let the timber be wet when subjected to the process, and it is probable that at no distant date the core of the wood, or that portion of it between the heart and the point to which the creosote has penetrated, will become rotten; for to this point will have been driven the moisture contained in the wood. Here it must remain, for there is no escape through the creosote. It must consequently ferment, rot, and destroy the core of the pole.

In employing creosoted timber, care should be taken when the creosoted portion is removed, as is sometimes the case in fixing the tie-pieces at the foot of A poles, that the uncreosoted portion exposed be well tarred, and even where the same occurs above ground—as when slotting poles for arms—that it should in some way be preserved from the effects of wet. No great time since, when railway companies began to make use of creosoted sleepers, it was not an unusual thing to see them fitted for the chairs after they had been submitted to the process. The natural consequence was that the point at which the greatest durability was required was the first to decay. We now see sleepers fitted before being creosoted.

Neither should it be forgotten that, whilst creosoted timber is impervious to wet, it is not so to the sun's rays. A creosoted pole will always show on which side the sun shines. The oil is by his influence brought to the surface of the wood. Some of it evaporates, whilst the rest trickles down the pole, forming a little mass around its base at the ground line. It is desirable for this reason that such poles should occasionally be served with a coat of tar. As to the period at which this should be done, the pole itself will be the best guide. Poles treated under this process differ considerably in the manner and measure in which they accept it. A damp, or a close-grained pole will not receive it so well as a dry or cross-grained pole. As soon as the pole assumes a light rusty brown color, then it is desirable to give it a coat of tar.

In 1870-71 a new line of poles were erected by the Postal Telegraph Department between London and Beachy Head. It was thought desirable that some of the poles used should be creosoted at the base. A large tank was obtained, and arranged so that a fire could be lit underneath it. In the tank was placed a quantity of creosote, which was kept at boiling heat, and the butts of the poles were submerged in it. A man kept in attendance looked to the fire, and kept constantly laving the poles,

so as to secure an application of the process for 6 or 8 ft. of the butt-end of the pole. By this means some twelve or fourteen poles at a time received a very fair surface-coating of creosote, the wood being penetrated from $\frac{1}{4}$ to $\frac{3}{8}$ in.

In conclusion, then, we may gather from the foregoing: 1. That creosoted poles, planted twenty-five or twenty-six years since, are still, apparently, in a state of perfect preservation. 2. That poles fitted with iron sockets which exclude the moisture from the wood, planted twenty years since, are still in a good state of preservation. 3. That specially-selected foreign timber, Burnetised, has lasted with repairs from eighteen to twenty-four years. 4. That Boucherised timber may be said to last ten to fourteen years. It would thus appear, that with those systems classed under the head of preservation by a salt, by which *moisture is contracted*, we have a varying and uncertain extension of the life of timber; but in no case is this extension such as to compete with that secured by creosote, by which *moisture is rejected*.

HORSE POWER OF BOILERS.

By W. BARNET LEVAN, Engineer.

The following trial of a boiler by evaporation and by Indicator diagrams was made August 5th, 1873.

The boiler supplied exclusively for this purpose belongs to an engine of the Cocheco Manufacturing Company, at Dover, N. H.

DESCRIPTION OF THE BOILER.

The boiler consists of a cylindrical shell, 16 ft. in length, and has a uniform diameter of 54 in., and contains in its lower half 80 iron tubes, each 15 ft. long and 3 in. external diameter, which are secured to the two heads in the usual way, and act as tube plates; the front head is set back 12 in. from the end of shell, to form a smoke chamber, the top of which has an outlet of sufficient area to carry off the products of combustion.

The brickwork forms a flue at the back end for the hot gases to pass from the furnace underneath and through the tubes, thence up the chimney.

There is a steam drum running parallel with the boiler, 8½ ft. long, 30 in. in diameter, secured to the top of the shell by two 4-in. wrought-iron necks, 9 in. long.

The whole boiler, as described, is elevated 48 in. so as to allow for a furnace 18 in. in depth between boiler and the grate bars, and an ash pit 24 in. below the latter.

The following are its principal dimensions and proportions, viz.:

Total length in feet	16
Total length in inches	54
Total height in feet	8.66
Total number of tubes	80
External diameter of tubes in inches	3
Internal diameter of tubes in inches	2.75
Length of tubes in feet	15
Length of steam drum in feet	8.50
Diameter of steam drum in inches	30
Length of grate bars in inches	64
Width of grate bars in inches	56
Total grate surface in square feet	25
Heating surface in tubes in square feet	864
Heating surface other than in tubes in square feet	152
Total heating surface in square feet	1,016
Ratio grate to heating surface	1 to 40

THE ENGINE

Is one of Babcock & Wilcox's horizontal expanding condensing engines. The following are its principal dimensions:

Diameter of cylinder in inches	18
Length of stroke in inches	48
Diameter of air pump in inches (double acting)	10
Length of stroke in inches	12
Stroke of steam valve in inches	7
Number of strokes per minute	60

The cylinder is encased by a steam jacket, also the ends having free communication with the boiler, whereby the cylinder is maintained continuously at a high temperature. The bed or framing is bolted to the end of the cylinder, and extends to the pillow block, and the metal is so disposed as to give the greatest rigidity with the least weight. The cross-head is upright, and supported on flat sides, a drip cup cast on the bed serving to catch all drippings, not only from the slides, but from all the stuffing boxes.

In addition to the steam jacket for preserving the temperature of the cylinder, a covering of felt is employed around all the exposed parts, and this in turn is covered by a casting of polished metal; the latter being the best protection against loss by radiation.

The valves are four in number, having each a motion at right angles to the centre line of the cylinder, and are flat gridiron

slides, working on seats of corresponding form; the latter are made separate from the cylinder, so that they can be readily removed when necessary.

The motion is given to the expansion slides through an adjustable wedge-bar, moved by an eccentric, through a rocking lever in the usual way; the arrangement being such that the amount of lead, release, and compression, can be varied at pleasure while the engine is in motion. Each steam valve on the top side of the cylinder has in it ten openings disposed in two parallel rows, each opening being 1 in. long by $1\frac{3}{16}$ in. wide on the face. The distance between the openings are $1\frac{7}{16}$ in., so that when closed the bars of the valve lap the opening in the seat $\frac{1}{4}$ in. on each side, and the total movement required to give the valve a full opening is $1\frac{1}{16}$ in. The motion actually given is $1\frac{1}{8}$ in. The openings in the face of each admission valve terminates at the back of the valve in two parallel longitudinal openings or ports 10 in. long by 1 in. wide, and these are fitted with expansion valves moving parallel to the centre line of the cylinder and at right angles to the admission valves, which are moved by a small steam cylinder fitted with a piston parallel to centre of cylinder and controlled by the governor, the latter regulating the points of the stroke at which steam is admitted to the small cylinder in which the piston acting on the expansion slides works. The exhaust valves are fitted, as above, to ports at the bottom of the cylinder, and have but one row of six openings, these being $3\frac{3}{4}$ in. long and $1\frac{3}{16}$ in. wide on the face; the spaces between the openings and the motion is the same as the steam valves.

The spindles of the wedge bars for giving motion to the valves, are each coupled to a strap which encircles the corresponding wedge bar, and which is traversed by a pin carrying the roller on which the wedge bar acts. The motion of which is at right angles to that of the valves, and each is kept in its place by a cast-iron guide, which also guides the strap on the end of the valve spindle.

The wedge bars for moving the steam and exhaust valves are connected by a rod fitted with right and left-handed screws so they can be adjusted when in motion. The two steam wedge bars are connected to the upper and the two exhaust ones to the lower end of the rocking lever, and the direction of their motions are thus always opposite to each other.

The wedge bars are of cast iron and the slots faced with steel, the latter being $8\frac{1}{2}$ in. long, the stroke being 7 in.; this excess allows for adjustment. The length of the connections can be lengthened or shortened so the inclined portions of the wedge bars will act on the valve either earlier or later in the stroke; they all being independent, each valve can be properly set by the indicator while the engine is running. The independent steam cylinder which moves the steam cut-off valves is fitted with a piston valve which controls the admission and exhaust by being connected to the governor, admits steam to either end of this cylinder alternately, the point of the stroke of the engine at which the admission takes place, and at which consequently the expansion valve is caused to cut off the steam, being controlled by the position of the governor balls.

The ports through which the steam is exhausted from the small cylinder are so situated that the piston travels over them, and thus at each stroke a certain quantity of steam is shut in the cylinder and thus serves as a cushion to arrest the motion of the expansion valve.

The governor is peculiar and is shown in Fig. 3.

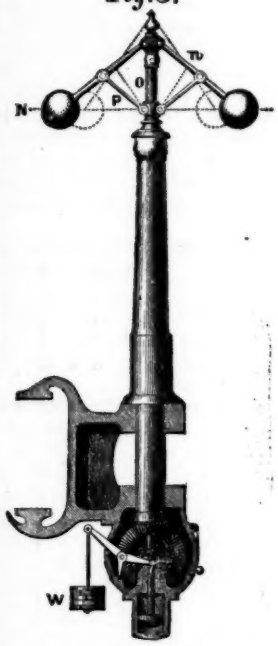
The balls, N, are hung upon arms in the usual manner, which arms are jointed at their upper ends to a head attached to the rod, O, which slides within the hollow shaft that drives the balls, the motion being communicated through the radius rods, P, which are jointed at their lower ends to the gearing shaft and at their upper ends to the centre of the arms, N. The rods, P, are half the length of the arms N, measuring from the centre of the ball, and it will be readily seen that in consequence of this arrangement the arms N, and rods P, form a parallel motion and compel the balls to move outward in a horizontal plane.

In the ordinary pendulum governor, the balls move in the arc of a circle and rise as they extend. It therefore requires an increased speed to maintain them in their advanced position.

The engine must consequently run faster when the load is light than when it is heavy, and such is the case with all ordinary governors. In this improved governor it will be seen that the gravity of the balls has no tendency to move them in either direction, and exerts

no influence whatever upon the speed of the engine. The centrifugal force causes them to diverge, and a weight, W, tends to bring them towards the shaft; when, therefore, these two forces are in equilibrium, the balls will remain in the same position, but as either preponderates they are moved in a corresponding manner, thus affecting the speed of the engine by varying the amount of cut-off. The weight, W, is supported upon a bent lever, which is so proportioned

Fig. 3.



that the centrifugal force at any given speed will just balance the weight in all positions. The speed of the engine will, therefore, remain at that fixed point with all variations of load or pressure of steam; for any increase or diminution will cause either the balls or weight to preponderate, and the point of cut-off to be changed, until the speed is again brought to the standard where the two forces are in equilibrium.

Any desired speed can be obtained by altering the weight W, and the action of the governor will be as perfect in one case as in any other. A spiral on the rod, O, serves to advance or retire the crank M, relatively to the main crank, so as to cause the cut-off to occur earlier or later in the stroke, as the balls diverge or converge, and the amount of this adjustment is such that the cut-off may be varied from nothing to seven-eighths stroke.

The standards which support the cylinder are hollow, and form a part of the condenser.

The air pump is bolted to the sides of the condenser at an angle of about 15 deg., and is worked direct from an eccentric on the main shaft. It is double-acting and is 10 in. in diameter, with a stroke of 12 in. The valves are india-rubber, and are arranged on gun-metal seats. The pump barrel, also, is lined with gun metal, and the air-pump piston is of the same material. The front head has the guiders cast fast to it, and is fitted with a cross-head to which is attached the air-pump rod and connections to drive it.

MODE OF CONDUCTING THE EXPERIMENTS.

The trial consisted in measuring the quantity of water evaporated and weighing the coal burned, and taking indicator diagrams every twenty minutes during seven hours. Fire was started under this boiler early in the morning of August 5, 1873, and the water brought to the usual height at 8 A. M., when the trial commenced. All the ashes were removed from the ashpit, and all the coal removed from the floor in front of this boiler. A pair of scales were provided and tested for weighing the coal and ashes.

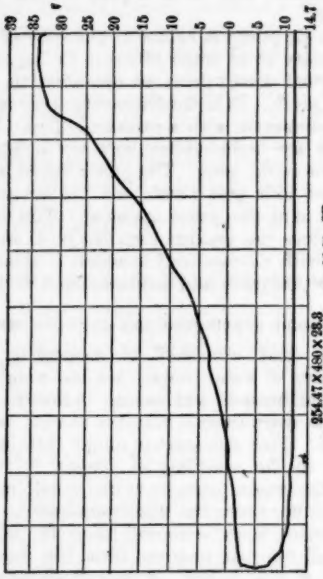
Total amount of coal consumed in pounds, was....	1,072
Ashes and clinker withdrawn from ashpit in pounds	31
Total amount of combustible in pounds.....	1,041

The quantity of water evaporated was measured in two wooden tanks constructed for the purpose, and connected with the force pump for supplying this boiler.

The tanks were 10 ft. long, 3 ft. wide, and 4 ft. deep; each tank had a rod plainly and accurately marked in inches, placed in the centre. Thirty-three inches in depth of No. 1 tank was evaporated, amounting to 142,560 cubic inches, and 37 in. of No. 2 tank, containing 159,840 cubic inches. The whole quantity evaporated was 302,400 cubic inches, equal to 175 cubic feet, at the mean temperature of 90 deg. Fah., or 10,856 lbs. A cubic foot at 90 deg. weighs 62.04 lbs.

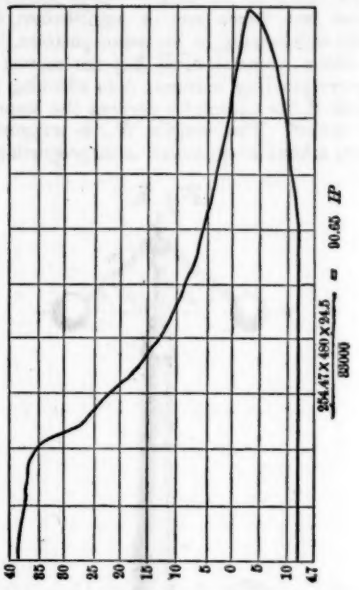
The coal used was a first quality of Lackawanna, a dry, free-burning anthracite, destitute of bitumen, burning without

smoke, and containing but little earthy matter, which was received in 1872, and under cover, giving a residuum of only *three per cent.* The quantity consumed was carefully weighed, as was also the waste in ashes in a dry state.

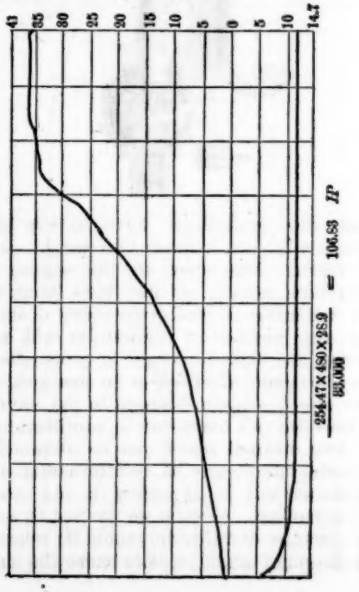


During the test the pressure of the steam per gauge, and its temperature, also the temperature of the feed water, and the product of combustion as they left the boiler, were taken every twenty minutes. The temperature of the feed water was observed in the feed pipe just before it enters the boiler, by a thermometer, the bulb of which was inserted in a hollow plug of iron, screwed vertically into the upper side of the feed pipe, open at the top and closed at the bottom, so that the lower portion of the plug was in the current flowing through the pipe; to insure the prompt conduction of heat, the cavity of the plug was filled with mercury. The steam pipe was arranged in the same manner. The advantage of this mode of applying thermometers is, that the thermometer is not exposed to pressure, as it is when directly inserted in the pipe, and in the event of breaking, no leak from the pipe ensues, and a new thermometer can immediately be substituted without interfering with the test, and the plugs, which are inexpensive, can remain in the pipe.

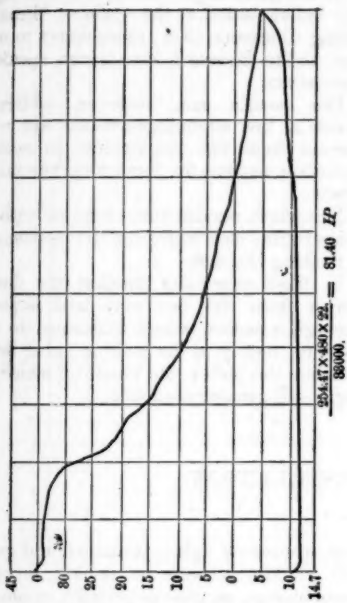
The steam pressure in the boiler was given by a large steam gauge. The temperature

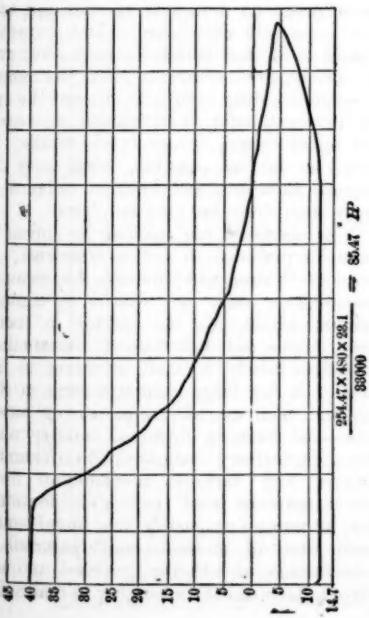


of the gases escaping from the boiler was also observed by a pyrometer inserted in



the flue about 12 in. from the boiler. The temperature of the air was also observed in several places.





The thermometers used are known in the trade as chemical thermometers; the whole instrument, including its porcelain scale, being inclosed in a glass tube; after the test they were carefully tested. The indicator used was an excellent instrument, and diagrams were taken from both ends of the cylinder. Average specimens of these diagrams will be found in cut.

Mean temperature of water in feed pipe in deg. Fah. 90
Mean temperature of steam in steam pipes " " 281
Mean pressure of steam in boiler in lbs. per sq in.. 39.9
Mean temperature of products of combustion deg Fah. 400
Mean temperature of air in boiler room in " " 87
Water evaporated from the initial temperature of 90 deg. by each pound of coal $= \frac{10856.00}{1072} = 10.12$.

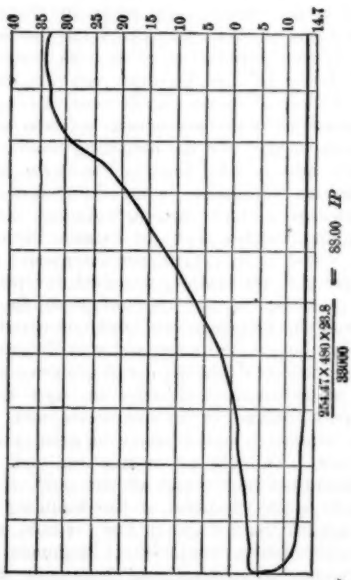
This reduced to the evaporation from and at 212 deg., by Rankin's formula, viz.:

$$\lambda\, 2'\, 1 = 1092 + 0.3\,(T_1 - 32°) - (T_2 - 32°)$$

T_1 = the temperature of evaporation of saturated steam at 39.9 lbs. pressure..... 267.3
T_2 = temperature of the feed water in deg. Fahr..... 90.

Substituting the values of T_1 and T_2 we have the formula:

$$1092 + 0.3\,(267.3 - 32) - (90° - 32°) = 1104.59$$



which is the total heat per pound of water evaporated, this being the multiplier of the observed weight of water evaporated by each pound of coal burned, which, being di-

vided by 966, the latent heat of steam gives the weight of water which would have been evaporated by each pound of combustible, had the water been both supplied and evaporated at the boiling point corresponding to the mean atmospheric pressure,

$$10.12 \times 1104.59 \div 966 = 11.56 \text{ lbs.}$$

of water, had it been supplied and evaporated at 212 deg.

RECAPITULATION.

Total weight of water evaporated in pounds in seven hours	10,856
Total weight of water evaporated in pounds in one hour	1,551
Cubic feet of water evaporated in one hour	25
Average horse power per hour of 21 diagrams during seven hours	85
Horse power per cubic foot of water evaporated.	
Horse power per cubic foot of water as per average of 21 diagrams feed water 90 deg	3.40
Coal per Horse Power.	
Pounds of coal per horse power, per hour	1.80
Water per Horse Power.	
Pounds of water evaporated per indicated horse power, per hour	13

Of the general performance of the engine and boiler tested at the Cocheco Manufacturing Company, it is unnecessary to mention, as the figures I have given speak for themselves.

The results are, however, additional proofs of the advantages which are to be derived from the employment in mills of first-class engines for furnishing the motive power.

The above results were obtained with low temperature feed water for the convenience in making the test.

In their every-day practice, the feed is drawn from the hot well, and is passed through a heater, which increases its temperature nearly to the boiling point before it enters the boiler, the result of which being a still greater economy.

FIRE-PROOF CONSTRUCTION.

From "Iron."

It is not many years since the literary world was at once entertained and instructed by the publication of a book entitled "Fallacies of the Faculty," wherein false pretensions of divers kinds were ruthlessly exposed as by an anatomical process, with a keen insight and an unsparing hand. It is not only in the "Faculty," however, that there are "Fallacies;" and every now and again comes some startling calamity, to test and, as it would seem, to expose, through the ordeal by fire, false pretensions and fallacies in Construction, so-called fire-proof. Of this class is the tremendous conflagration at the Pantechnicon, which occurred on Friday last, in the very centre of Belgravia —the focus of fashion—withering up with its fiery breath, not only an amount of property valued at an enormous sum, but also what is or should be of far greater consequence, namely, an unthinking and unenlightened confidence on the part of the public in the resources of the building art, as against the ravages of fire; which, were it well founded, would be of immense importance, but which, being or seeming to be fallacious, has been and is, productive of grave evils.

To be the Cassandra of the press is to fill a thankless office; such functions, therefore, are rarely lightly assumed, and generally quickly, perhaps too quickly, set aside; nevertheless, at critical periods, in the continued presence of an ever-nascent risk, and more especially when some violent outbreak —such as of that faithful servant, but awful master, fire—comes to point the moral, it becomes a duty to turn to account the opportune text, even to reiteration, in season and out of season, of unwelcome truths; to show, as far as possible, what may be deemed fallacious, and wherein reliance, if haply such there be, may be placed.

It is needless, nay, useless, to appeal to recent experience in other countries; to point to Boston and Chicago, for instance, inasmuch as cases are altered by circumstances, which, for the matter in hand, mean modes and materials of construction. It suffices briefly to recall attention to the facts of a few large conflagrations in this city and country, of comparatively recent date—the burning down of country mansions, Canterbury Cathedral, the Alexandra Palace, and various metropolitan fires, which scarcely need particular identification by name—to justify the broad statement that all methods and materials of construction, as hitherto practised and employed, have failed thoroughly to realize the

desirable quality of being absolutely fire-proof; there are, doubtless, various combinations of certain well-known materials, such as iron, stone, and brick, to the entire exclusion of wood, which profess to be, and pass for being, fire-proof, a quality which, to a greater or less extent, they possess, but only in comparative degree; whereof the proof is found in the fact that, whereas they may withstand the test of the ordinary run of fires, yet they fail ignomoniously to pass unscathed through the fiery baptism of any conflagration of exceptional magnitude; and there can be no more remarkable illustration of this inherent weakness than the "Pantechnicon" itself, wherein every possible precaution had been carefully studied and adopted, every combustible material rigidly avoided and excluded, every fire-proof or presumably fire-proof material, carefully selected, lavishly employed, and skilfully combined—resulting only in complete and utter failure under the crucial trial.

Such failure, however, is by no means so surprising as the original confidence; for it is only to the superficial and unscientific observer that iron and stone, unprotected, assume the semblance of fire-proof materials. The expert knows that stone crumbles away, and that iron warps and buckles, nay melts, under the action of fire, more particularly when the agency of water is brought in contact therewith; so that, as a matter of fact, a sound beam of oak is more reliable than an iron girder or column. Good brickwork certainly approximates most nearly to the desideratum of fire-proof construction; but it requires to be very massive and well put together; as, otherwise, mortar perishing with heat, the coherence of the mass is apt to be destroyed by fire, so that, though an arch might stand, a wall might fall.

Is the conclusion, then, inevitable, that there is no such thing possible as thoroughly fire-proof construction? Not so; the proper corollary is simply that the failure lies, not so much in the materials themselves as in the manner of their use and the method of their combination; and herein lies the secret of success, that the wood, iron, stone, or brick, should be covered, isolated, and protected by special means and appliances. As for example, there are special fire-proof paints, which will, at least, go far towards protecting woodwork superficially; just as, also, it may be made uninflammable by "mineralization," or filling up the pores and fibrous interstices with particular ingredients. Similarly a coating of plaster is found to act materially as a preservative for iron against the destructive action of fire. We refer to these, not as being in themselves fire-proof expedients, but as subordinate elements in a system of fire-proof construction; and more particularly as the principles involved have really been practically embodied in a special invention of a method of construction which we have previously described, and at intervals referred to. And having no other interest in the matter than the general good, and a desire for the prevalence of sound doctrines, we have no hesitation in making farther brief notice thereof; more especially as it has quite recently been adopted as a preservative and precaution against fire by one of the most prominently known of capitular bodies, under the advice of one of the most eminent of English architects, in one of the largest and most noted of metropolitan public buildings—St. Paul's Cathedral.

Startled into the consciousness of latent but ever-present danger, by the catastrophe at Canterbury Cathedral—in itself only a repetition of similar preceding disasters, such as those at York Minster, on two occasions, and others perhaps not quite so well known—the Dean and Chapter of St. Paul's Cathedral, solicitous to leave no stone unturned to secure the noble fane which is their anxious charge, called to their councils Mr. Penrose, who is their architect, with an especial view to the protection of the interior woodwork of the dome. In brief, the result of Mr. Penrose's researches and inquiries has been that an efficient fire-proof lining has been provided for the same, which has just been completed by Mr. P. Brannon, C. E., of Parliament street, Westminister, upon his patented principle of construction.

Mr. Brannon's mode of construction consists in the employment of webs of iron wire, angle-iron ribs and framing, and the like, combined with a peculiar fibrous concrete of filamentous materials, with cement, gravel, or old bricks and rubbish, the whole concreted together and compressed into a fabric of great strength, perfectly unaffected by fire; wherewith may be constructed in any desired form and thickness the entire component parts of a building, whether dwelling house or other, such as walls, flat floors, ceilings, and roofs, chimneys and

flues, stairs and doors. The advantage of this principle and method of construction—apart from its quality of being perfectly fire-proof—is that it is not merely a special and expensive device, suitable only for large and costly buildings for purposes of trade, commerce, and industry; but that it is economical and perfectly adapted for the building of a cottage, a shop, or a dwelling house, upon a small or a large scale. In fact, such houses and cottages have not only been built and inhabited, but absolutely tested by conflagrations, of combustible substances piled up therein and ignited—without the slightest injury and detriment being the result—the ravages of the fire being strictly limited to the space contained between the walls and doors, floors and ceilings, without spreading or communicating in any way from one room to another, upward, downward, or laterally. Now, although in relation to the behavior of such a material, and the resisting powers of such a building, in the ordeal of a tremendous conflagration, there can be nothing more than fair presumption, until chance brings about such a thorough test; yet, so far as such a thing is practicable, there is *prima facie* evidence of a favorable and satisfactory result. Hence Mr. Penrose's investigation having brought these facts, unsolicited, to his knowledge, has resulted in the adoption of Mr. Brannon's principle for the protection of the timbers in the dome of St. Paul's Cathedral, as mentioned.

The manner in which this work has been carried out is peculiarly suggestive of what may be accomplished towards the attainment of effectual security against the hazards of fire, in the case of existing structures. The first portion dealt with has been that section of the inner and outer domes through which passes the approach to the highest gallery, and the ball, which is therefore most exposed to risk, as being accessible to the public. In this portion, which comprises five compartments, situated between two of the flying buttresses, the whole internal surface has been completely covered with fire-proof casing, formed of the patent stone felt, surrounding the whole of the woodwork, with air space between, maintained by the insertion of isolating blocks of stone felt with insulating washers of alumnized felt, through which pass the screws or other means of attachment to the wood. Externally the fire-proof casing is made ornamental by being worked in panels, and the connections with the stonework are suitably made perfect. Panels, for the inspection of the exterior dome, and doors of partition, made of the same fire-proof material, are provided and fitted with fire-proof rabbetings and weatherings, so that the whole compartment is entirely insulated from those adjoining on either side. Similarly the wooden steps, treads, risers, and landings have been covered with fire casing, so that, in fact, there is absolutely nothing for the flame to get hold of, or be nourished by. It is difficult to conceive any protection which should be more complete and effectual for existing structures.

THE IRRIGATION WORKS OF INDIA.

From "Engineering."

There can be no doubt whatever that in former times under native rulers of India large tracts of country were very extensively irrigated. Commencing with the basin of the river Indus and the Punjab, there was an extensive system of well irrigation and of inundation canals. The district of Multan, between the Sutlej and the Chenab, where rain hardly ever falls, was a succession of beautiful gardens, shaded by date palms, the corn and fruit abundant; the Afghan rulers, left by Aurunzeb, developed this to such an extent, that one of them cleared for himself from them a private fortune of nearly a million pounds sterling. There were also other inundation canals in Gugaira and other districts of the Bari Dooab above Multan; of these the Kanwah and Sohag canals are best known, and a more complete system in the rich country of Muzaffargarh, between the Chenab and the Indus, the land under the influence of which was one sheet of cultivation. In the Shahpur district there were several inundation canals drawing their supply from the Jhelum. In the Derajat, on the right bank of the Indus, there were 12 inundation canals, having an aggregate length of 291 miles, running parallel to the Indus, and filling themselves from it in the periods of annual inundation. The native State of Bahawulpur, on the south side of

the river Sutlej, was also partly irrigated by inundations. In fact, in former times such canals were conducted from all the five rivers of the Punjab, traces of them, and the ruins of cities and villages on their banks, being still visible; ravines and water-courses of small rivers or their branches, that are now dry, or have had water diverted from them either by natural processes, or by want of repairs or proper maintenance, were formerly used for conducting water for irrigation, which was then raised from them on to the fields by means of Persian wheels. It is, of course, quite impossible to determine the acreage then under irrigation; it was probably a very high percentage of the cultivatable area; but there is no doubt that some of these canals were large, notably those from the Chenab, named the Minchinwah, Barus-wah, and the Sadik-wah, which were channels 100 ft. to 200 ft. wide. The immense numbers of ruined canals of different sizes all over the Punjab and Bahawulpoor, cannot fail to produce to the imagination a most flourishing and populous country of the past; and when, too, we find that these natives kept also their towns well supplied with water, fountains, tanks, and baths, as may be discovered by examination of traces and old ruins in Lahore, Amritsir, Delhi, Kurnal, and countless other towns, we cannot but feel mortified as well as astonished at the inferiority and paucity of similar results under British rule.

In Sind, the country lying on the lower 450 miles of the river Indus, inundation canals were formerly both numerous and important; they varied in size up to 100 ft. in width, 10 ft. in depth, and 80 miles in length before branching off into smaller canals. Those positively known to have existed on the western bank of the Indus are as follows: The Sind Canal, having its off-take 21 miles below Sakkhar, 66 miles long, before dividing itself into three branches, the Mutti, the Kadu, and the Mihshuda. The Ghar or Larkhana, leaving the Indus 23 miles below Sakkhar, and having three heads or channels of supply; this is very tortuous, and eventually divides itself into two canals, the Nurwah and the Nowrung, which again sub-divide themselves. The Western Nara Canal leaves the Indus 27 miles below Sakkhar, and returns to it at Sehwan; at 40 miles from the head it is 200 ft. to 300 ft. wide; the country is well cultivated on either side of it and the villages are numerous. The Bigari Canal had a total length of 48 miles with a fall of 35 ft.; the head was on a side channel, 7 miles from the Indus; it was 24 ft. wide and 9 ft. deep at the head in 1844, but then much reduced from its original size. For the first 23 miles it passed through a country covered with scrub, but presenting frequent traces of former cultivation; for the remainder of its course water was taken from it by means of Persian wheels; its principal branch was the Nurwah Canal, entering far into the desert north of Khangarh.

On the eastern side of the Indus, the principal ancient canal was the Eastern Nara, called the Puraun in its lower course; it irrigated a large tract of country, part of the great Thar or Indian desert, sometimes spreading itself into lakes, of which there were as many as 400. There was also the Fullali Canal, the main feeder of irrigation channels from Haidarabad southward and eastward; originally it was a natural branch of the Indus, joining it again at a point 16 miles below Haidarabad, but the Amirs diverted the water by a dam, sending it to supply the Gaja, the Guni, and other canals to the south; the chief portion thus fell into the Guni after a course of 40 miles, the average width being no less than 350 ft. In the North-West Provinces, or what is called Hindustan proper, the Emperor Firuz Shah constructed the Western Jumna Canal, conducting water to Hissar; a branch from this to Delhi was made by Ali Murdan Khan, under the order of the Emperor Shah Jahan, in 1626; it crossed the lowland by a masonry aqueduct, crossed the Aravalli hills in a rock-cutting 60 ft. deep, and flowed through the city in a masonry bed, throwing off innumerable smaller streams. The great halls and courts of the palace, the fountains, marble baths, reservoirs and gardens, were supplied by numerous channels from it. This state of things lasted for 150 years until the year 1753. Ali Murdan Khan also constructed another canal in the Dooab, east of the Jumna, under the Emperor Shah Jahan in 1650; it was neglected and fell into disrepair, but was restored in 1764 by a Rohilla chief, Zabitha Khan. In the neighborhood of Delhi is a chain of natural lakes or jhils, the principal of which were the Najafgarh and the Kotida; these, collecting the drainage of the slopes from Delhi to Budshahpur, were formerly em-

ployed in the irrigation of the country around and below them.

Besides these works, an examination of the ruins of Old Delhi, better known as Toghlukabad, about 10 miles from New Delhi, or Shahjahanabad, shows remains of a canal, of extensive reservoirs, made or walled with concrete and cut stone, and undoubted traces of a complete system of irrigation and water supply. The magnificence of the beautiful ruins of immense tombs, mosques, palaces, halls, markets, and pleasure gardens with fountains and water channels in exquisite taste, prove that this must have been on a large scale. A careful examination of the whole of the portion of country on the right bank of the Jumna below Delhi, and a certain part of that on the left bank, shows that there must have been an immense number of tanks or artificial reservoirs, probably one or two near each of the large villages, from which irrigation was carried out. The traces of these are for the most part entirely obliterated, but enough remains to show what must have been the state of the North-West Provinces as regards irrigation under native rule. In Rohilkhand water was collected by damming up the hill streams, and leading small canals from them over the country; in 1824 there were 1,930 dams and 915 canals; all the country between the Ramgunga and the frontier of Oudh is intersected by hill streams, from whence canals could have been, and probably were led. As to Bundalkhand, there is no record of what was done in the olden time, though probably a careful examination by an experienced hydraulic engineer might discover many traces of irrigation.

In Rajputana large reservoirs still exist; others have gone to ruin, and barely show their traces; these are more especially in Jaipur, Udaipur, Jesalmir, Bhurtpur, and Alwar. As to the large province of Bahar and Upper Bengal, there are unfortunately no records of former native irrigation; the province of Orissa, inhabited by a particularly slow and indolent race, probably had comparatively little native irrigation. The forementioned provinces may be said to comprise the whole of Northern India; Southern India, which includes everything south of the Vindhya Range, or the general latitude of the courses of the rivers Narbada and Mahanadi, has features peculiar to itself as regards irrigation, depending on the general formation of the country. This, consisting generally of large plains having a very gradual fall from the Western Ghats to the Coromandel, admitted of tanks and reservoirs being made on a very large scale; these are therefore very numerous in certain districts, and occasionally are very large. Taking the provinces in order going southward from the Narbada, the Central Provinces and Berar have a comparatively small number of old works of irrigation, although a fair number of ruined tanks of a small size still exist, and there are undoubted traces and traditions of some few dams. The towns of Akola, Ellichpur, Burhanpur, and others, were once well supplied with water. In Nimar, Kandeish, and the Bombay Presidency there were still fewer of these, the falls and form of the country being unfavorable on the whole, the rivers having but a slight slope, and the transverse slopes of the valleys being so great as to prevent canals from them from getting to a sufficient distance from the parent stream. In the large native State of Haidarabad, the eastern and southern portions have a large number of tanks, some of them rather large. The city of Haidarabad has a large artificial lake, called the Hosen Sagar, close to it, and the city of Aurungabad has the remains of a very extensive system of water supply, the water for which came from several distant sources; of this, one channel driving a very primitive turbine and supplying a large fish pond, still exists. In the fourteen districts of the Madras Presidency there are 43,000 native tanks, with about 30,000 miles of embankments, yielding a revenue of one and a half million pounds sterling, yet up to 1853 the English had not made one, although many had been allowed to fall into disrepair. The number of tanks in some of these provinces is thus given in the "Progress Statement" for 1873.

Visagapatam	26
Godavari	?
Krishna	89
Nellor	116
Karnul	15
Ballari	114
Kadapa	75
North Arcot	477
Salem	91
South Arcot	218
Coimbator	29
Trichinapali	85
Tanjor	64
Madura	115
Tinnavelli	522
	1886

This table barely accounts for two out of the forty-three thousand mentioned; the remainder possibly being in Mysor, Haidarabad, and Travancor. In Mysor there must have been a very large number of them besides these; the waters of the rivers in Mysor were utilized by means of dams and channels. Some are very large; the Viranum tank has an area of 35 square miles, and a dam 12 miles long; the Chembrumbakum tank has a dam 3 miles long, and irrigates 10,000 acres of rice cultivation; the Kaveri-pak tank has a stone revetted dam 4 miles long, and irrigates 7,700 acres.

In the Krishna district there is a dam of stone 3,750 ft. long, and 305 ft. broad, with canals from it on each bank; the English acquired the Krishna delta in 1766, and did nothing for it for 80 years, while famines periodically devastated the land; in 1833 not less than 200,000 people, out of about a million, died of hunger, and the Government lost nearly a million pounds sterling of revenue. In the Balari district the rajahs of Tizianagur constructed dam and canals from the river Tungabudra in 1521, nine dams, and 89 miles of canal; the city of Vizianagur with its suburbs was formerly also plentifully supplied with water. The great Kaveri dam, of solid stone, 1,080 ft. long and 40 ft. broad, was constructed 1,600 years ago. In Tinnavelli there were formerly a large number of dams and canals from the river Tambrapurni, many supplying tanks.

In giving the above account of native works of irrigation, it must be remembered that those alone have been mentioned of which there is positive record; it is probable that there were formerly very many more of which the memory and the traces have entirely passed away; enough, however, have been rediscovered and mentioned above to prove that in former times, and under native rule, India was on the whole plentifully and well irrigated. The works were probably clumsy, slovenly, and defective according to our ideas of engineering, but they were efficient in irrigating the land, producing food, and supporting a population that, had it not been for civil and political discord, must have been in a highly prosperous condition.

MODERN IMPROVEMENTS IN ARTILLERY.*

By Capt. E. SIMPSON, U. S. N.

Says a military writer, in summing up an official report on the naval equipment of European countries: In considering the foregoing report on the artillery of England and other European countries, the first and most important feature to be noticed is, that it consists almost entirely of rifled cannon. Some smooth-bored guns are yet in use, but they are simply retained because the conversions in progress and the new constructions have not yet been able to supply a sufficient number of rifled guns to replace the smooth-bores, now considered obsolete. It will be remarked that, in all countries reported on, great activity is apparent in the arsenals, in order to complete the reform universally acknowledged to be necessary.

Apart from the increased range and accuracy due to the rifled system, the introduction of iron armor for ships and forts is a sufficient explanation of the cause of this change in the character of the artillery, as it has been conclusively proved that, in order to operate against the new defence, a radical change must be made in the character of the attack.

The experience of the United States Navy during our late Rebellion, showed that, even against our poorly-armed monitors, the effect of 11-in. smooth-bores was not serious, and these guns would be totally ineffective against the better-armored vessels of the present day. When wooden walls were the only defence at sea, no gun was superior to the Dahlgren 11-in. smooth-bore; but the new character of defence robs it of its power, and as it constitutes the heaviest armament of our cruising vessels, it is evident that against armored vessels we are harmless for injury. The necessity of a change in armaments, recognized by all the world except ourselves, must force itself upon the mind; unless we can believe that it is possible for us to be right, and all the rest of the world wrong, which, in view of the intelligence and

* Report on a Naval Mission to Europe. Washington: Government Printing Office.

ability displayed by European artillerists, would be a presumption difficult to establish.

Premising that the necessity of a change in our naval artillery is recognized, it remains only to carefully select from foreign systems what may be considered the best, and either to adopt it as a whole, or with such improvements as the latest experience may suggest. There is no doubt that, at the present time, we find ourselves in a most favored position for coming to a judicious conclusion on this subject, as we are at liberty to take advantage of the results of most exhaustive and expensive experiments, which have been carried on by foreign powers; and, in considering the subject, and weighing one system against the other, our minds are free from any national bias, and are not likely to be influenced by prejudice. Each Government which has originated a system is naturally wedded to its own invention, and looks through a distorted medium at that of a rival power; while a Government uncommitted to any system, is free to detect flaws and to recognize perfections.

Before deciding upon a system of construction for the new artillery, the first point to decide is whether the gun should be a breech-loader or a muzzle-loader. In reviewing the foregoing report, it will be seen that in all countries of Europe, England alone excepted, the breech-loading systems of Krupp, and that adopted as the French system, are recognized as being successful; thus the question as to the practicability of carrying out the project is solved, and any unprejudiced mind must acknowledge that a breech-loading cannon is a success. The success of the system of breech-loading is demonstrated for all calibers, the most formidable cannon in Europe being of that construction. The practice in England, so persistently quoted by the enemies of the breech-loading system, is alone opposed to the introduction of a breech-loading cannon; but there is reason for this. The English artillery is founded upon the system of construction introduced by Sir William Armstrong, and the original invention of Armstrong involved the principle of breech-loading, and had his system of breech-loading proved as successful as his system of construction, there is no doubt that the artillery of England would be breech-loading to-day; but experiments proved that the breech-loading system of Armstrong was very defective, and after much money had been expended in a blind effort to make it practicable it was definitely abandoned, and the fault of the *system* was charged to the *principle*, which was declared to be impracticable, and was thrown aside, and the muzzle-loading principle was retained. Here is an instance of a prejudiced adherence to a national invention. No efforts of a system from abroad, although the English mind was ready to embark in the breech-loading system; it was sufficient that the English invention had proved defective, and this fact blinded the eyes of the Government to the advantages possessed by other systems. The Government committed itself entirely to the muzzle-loading system, and the plant at Woolwich was accordingly established with a view to the sole manufacture of that species of gun. It would require now a most powerful demonstration of the superiority of the breech-loading gun to induce a change in the English system, but the minds of many of the most enlightened artillerists in England are impressed with the success of the system abroad, and recognize its advantages.

The struggle between the breech-loading and the muzzle cannon is much the same as that which existed between the breech and muzzle-loading small-arm not many years ago. The arguments made at that time against the introduction of the breech-loading musket are again repeated in the case of the cannon, yet no nation would now consider Brown Bess as a weapon fit for her infantry, and the breech-loading cannon must, in turn, be considered equally necessary for the use of artillery in the field or for the armament of ships of war.

For the latter purpose, the breech-loader presents so many advantages that it is somewhat remarkable that the necessity for its introduction on shipboard is not more readily appreciated. The facility of manipulation, the increased projection from the port, the protection to the gun's crew, are all points of most vital importance; and the piece, even after the bore is badly deformed, recommend it as a system promising the most happy and reliable results in the day of trial. The chief point that objectors raise to the system is the want of safety—so claimed by them. But the result of years of experiment and practice, both with the French and Prussian systems, goes to show that this objection has no foundation in fact, and the experience of actual war-

fare is not wanting in order to prove that this apprehension has been dissipated.

In determining upon a system for *construction*, the prominent plans to be considered would be the following:

The Woolwich gun (Fraser's).
The Vavasseur gun.
The Krupp gun.
The French gun.

In connection with these, as original constructions, there would have to be considered the following systems of conversions, viz.:

The Parsons converted gun.
Pallisser's converted gun.
The Dutch converted gun.

To which would be added a consideration of the plan proposed by Mr. Bashley Britton for utilizing as rifled cannon the stock of cast-iron smooth bores, so as to make them efficient for the secondary purposes of artillery.

The Woolwich gun is made of wrought-iron coil, lined with a steel tube. It is thus composed of two metals, differing widely in their characteristics. The malleable character of the wrought iron is inconsistent with the elasticity of the steel, and repeated firings have the effect of separating the surfaces, by which means the steel tube becomes, in time, unsupported, and cracks.

The use of the steel tube, however, is found to be indispensable, as wrought iron is pronounced to be unfit for the bore of a gun of large caliber, burning a large charge of powder. The gun is styled a wrought-iron gun, and the metal of the tube is always blamed when the gun comes to grief; yet it is found necessary to use this metal, which is acknowledged to be an element of weakness and uncertainty in the construction. That this is so there can be no doubt; not, however, on account of the fault of the metal, but because the metal is not properly supported.

The Woolwich construction results in a very safe gun, but one which must be classed as short-lived, being deficient in endurance. The gun is safe after the tube is split, as has been often proved, but it cannot be considered as fit for service when in such a condition; hence the lifetime of the gun must be marked to the time of the cracking of the tube.

The Vavasseur gun is constructed with a steel tube of the same proportions as that of the Woolwich gun, but the body of the gun is built up of steel, thus giving a support to the inner tube of the same metal of which it is composed. There is a homogeneity throughout the wall of the piece, which results most favorably for the support of the tube. This gun is probably the most theoretically perfect construction that is in use, and the results of practice, so far as they have extended, go to prove the correctness of the principle. In the appendices of this report will be found reports by English and French artillerists on a 7-in. gun of this construction; and guns of larger caliber in battery at Callao, Peru, were found to be very formidable pieces by the Spanish fleet during their attack on that place.

The gun is made entirely of steel. The inner tube is entirely inclosed from breech to trunnions by a long jacket of steel, shrunk on, and constituting a constant reinforce. This is in turn reinforced by steel bands shrunk on, one or two layers, according to the caliber of the piece; and the chase of large pieces is also reinforced in like manner. The jacket is shrunk on lightly, the outer hoops at a great tension. The object of this is to force the inner tube to assist to its utmost in restraining the force of the charge before calling on the supporting parts for aid. The mutual support given by all parts in this construction is most perfect, and there can be no doubt of the wisdom of adopting such a system of artillery as this.

The Krupp gun is also of steel, but differs from the Vavasseur gun in the mode of construction. The reinforcing jacket used by Mr. Vavasseur, which is required to give longitudinal support to the thinner tube, is dispensed with, and the hoops are shrunk immediately on the tube, which is thicker than in the Vavasseur gun. The present Krupp construction is a change from its original mode, in which the entire wall was a solid casting, and he adhered to this practice until experience proved the necessity of *building up*. The modifications made from time to time in his construction have been gradual, but he constantly finds himself forced to approach the system of building up as practised by Mr. Vavasseur. The tube is still much thicker, and he has depended on the thickness of the solid tube to supply all the strength required for the chase of the gun, even though he now builds up on the reinforce of all calibers; but from late experience in Russia with a Krupp 11-inch gun, it is evident that the

chase must be built up as well as the reinforce, as, in the case referred to, the chase of the gun was ruptured.

Building up on the chase will be the commencement of the reduction of the thickness of the tube, which will be another approach to the Vavasseur type.

The French gun is a cast-iron gun, strengthened on the reinforce with steel hoops. There is no doubt that the gun proper is much strengthened by the inclosing hoops, as the effect of their compression is appreciable in the difference of the diameter of the bore before and after the shrinkage of the hoops; but it would be impossible to obtain the same strength or endurance from such a gun as from a scientifically constructed steel gun in which the tensile strength of the metal is much better, and in which the actual strength is increased by the elasticity of the material.

The Pallisser converted gun is a cast-iron gun lined with a tube of wrought iron. As it has been shown that wrought iron is entirely unfitted for the bore of a gun of large caliber, it is evident that the use of this conversion must be limited to small calibers, and even though these small caliber guns are considerably strengthened by the introduction of the wrought iron tube, yet the charges of powder used in them are not such as to warrant their being classed under the head of high pressure-guns for use against armor, but they must be always limited to the secondary uses of artillery, for which purposes the old cast-iron smooth bores, simply rifled and firing elongated projectiles, as proposed by Mr. Bashley Britton, would be nearly as effective.

The Dutch converted gun is the same as the Pallisser's, substituting bronze for the coiled wrought iron tube. All the objections to wrought iron for the tube of a gun obtain to a greater degree in the case of bronze, limiting a gun converted on this system to small calibers and a small number of fires, as the scoring that would take place in the bore would soon reduce the rifle-practice to a low standard of precision.

The only remaining gun deserving of note is the Parsons converted gun, which combines strength and endurance with cheapness when compared with other guns which give as good results. The main construction is the same as the Vavasseur gun, being a steel tube reinforced with a long jacket of steel; but Mr. Parsons dispenses with the exterior hoops of steel, and inserts his reinforced tube into an outer casting of cast iron, which supplies all the necessary strength for the exterior, and affords an opportunity of utilizing the cast-iron guns on hand. The experiments made in England and France with two guns, converted by Mr. Parsons, are recited in this report, and they show that no guns have ever exhibited more satisfactory proof of endurance. In closing this report, then, and after a careful study of all the systems in Europe, I would recommend the adoption of the Parsons system of conversion, combining with it the breech-loading arrangement of Krupp (or Broadwell) with the Broadwell ring for a gas-check.

In reference to projectiles the selection would rest between the adoption of the Prussian lead-coated projectile, and that patented by Mr. Vavasseur, and now adopted in France, in which there are inserted in the cylindrical part of the projectile two more rings of soft copper. In the former case, oxidation is said to destroy the close fit of the coating, although it is also claimed that the new method of soldering on the lead with zinc obviates this difficulty. No objection presents itself to the copper-ring system, which has been successfully experimented on by the French with their largest calibers.

The studded projectile is to be avoided. As used with the Woolwich gun in a gaining-twist, the effect of the passage of the projectile along the bore is to shear the studs, causing them to ride upon the lands, which might be attended by most serious results to the gun. The use of the studded projectile with a breech-loading gun results in the abandonment of most of the advantages to be derived from the breech-loading system. This projectile, long in use with the French breech-loader, is now abandoned, and the copper-ring projectile has been substituted, which develops the advantages of the breech-loader in giving increased range and accuracy, with less scoring of the bore.

The official report of the Vienna Exposition shows that England produces more than one half of the iron production of the world, North America about one-fifth, France about one-twelfth, and Belgium one twenty-fourth—these four constituting the great iron-producing countries of the globe.

ON SIMPLICITY AS THE ESSENTIAL ELEMENT OF SAFETY AND EFFICIENCY IN THE WORKING OF RAILWAYS.*

By Captain HENRY WHATLEY TYLER.

From "Journal of the Society of Arts."

The various classes of collision, and the accidents at facing points, may together be roughly stated to comprise from two-thirds to three-fourths of the casualties to railway trains which are considered of sufficient importance to require investigation on the part of the Board of Trade; and questions as to the arrangement and working of points and signals, and as to preserving intervals of time or space between trains and their accessories, enter more or less into the causes of such casualties. In 1872 there were 179 such accidents out of 238 investigated train accidents; in 1871, 105 out of 159; in 1870, 97 out of 122.

Within the ordinary limits of a paper of this description it would be neither desirable nor possible to enter into all the details of the apparatus employed by the different railway companies for points, for signals, and for train-telegraph purposes, or to discuss all their relative merits or defects. Such a description would, if complete, fill volumes; and in such a discussion it would be very difficult to deal, as the author would always desire to do, in perfect fairness with all competitors. It would seem to be preferable and more useful to put forward in this paper the principles involved, the requirements to be satisfied, and the direction in which further improvements may be effected. It is only by close attention to the constant teachings of practical experience on various systems of railways that the present degree of perfection has been reached; it is only by patience and perseverance in the same method, under the same instructor, that further advances in real improvement can be made; and it is only by the full application, proper working, and careful maintenance of the necessary appliances, that their due result in the diminution of railway casualties can be obtained.

There is, perhaps, hardly any subject in regard to which there has been more misunderstanding, or greater confusion of ideas, than simplicity in railway working. The author and his colleagues have constantly been accused of requiring complication when they have been seeking to introduce simplicity; and in adopting, for this reason, the heading of the paper as his thesis on the present occasion, the author would say a few words at the outset as to what is and what is not simplicity in such matters. It is, or ought to be, the object of the inventor or engineer, in his designs or his projects, his schemes, his plans, or his work. It is usually the last result which, after the greatest amount of thought, is attained. The same is true in other fields of work. Even in literary labor, perfect simplicity of diction, of description, of argument, requires the greatest thought and care, and is the most difficult result to arrive at. The Latin words *simplicitas* and *simplex* convey, no doubt, the idea of singleness—of one thing; and a simple machine is in the same sense a machine of few parts, while a complicated machine is a machine of many parts. But simplicity of construction and simplicity in working are in many cases distinct and different from one another; and, further, complication in construction is frequently necessary to obtain simplicity in working. This is equally true of a machine, of a railway, or of a sentence. Simplicity in working, as desirable, being the thesis, confusion in working, as undesirable, is the opposite idea presented for consideration in the present paper. As a confused sentence can sometimes only be made plain by dividing it into a greater number of parts; and as a machine can only in many cases be started and stopped, and made to work more easily, by adding to its parts in construction,—so also a railway may be worked more simply, with less confusion, more efficiency, and less risk, by the addition of certain appliances and accommodation, and by their proper adaptation to local circumstances.

Ingenuity, care, and forethought are required in their application, and time and experience for their development and further improvement. Railway working, which was at first easily conducted, is becoming a science, with its separate branches;

* A paper read before the Society of Arts.

and the author aims at no more in the present paper than an outline sketch, which he hopes may be filled up by a full discussion. He ventures to think that the time has arrived for such a discussion, and to hope that full latitude may be allowed for the expression of opinions from all classes and all parties interested in the subject.

The first important branch, then, of railway working to which reference may be made, is that of points and signals. When trains were few, and there was little risk of their interfering with one another; when they had the same regular stoppages, and the speed was not great; when junctions, stations, and sidings were less frequent,—then fixed signals were comparatively unimportant, the switches did not require to be so often moved, and facing or meeting switches were not the cause of so much risk. When the want of fixed signals was experienced, boards and lamps were fixed on revolving poles; and the expression "the board was on" or "the board was off" is retained amongst the engine-drivers on some of the older lines at the present time. The semaphore-arm, formerly so much used for telegraphic purposes, is now generally preferred as a railway signal. But its merits were not fully recognized until the "board" had passed through a great variety of forms, according to the ideas of the designers on different railway systems. The board was made round, square, triangular, oblong, fish-tailed, half-moon shape, long and thin, or short and stumpy, on different lines. In some cases two red discs, called spectacle-discs, were used for danger, and one green one for caution; and on the broad-gauge systems the disc was the all-right, while a cross-bar below it was the danger signal, and the arrow-head was used mainly as a time signal. So that the same indication was employed for danger on the narrow, and for all-right on the broad-gauge railways. Then, again, additions were made to these boards, discs, or cross-bars, by turning the ends up or down, or by excrescences at one side or the other, or by various methods, to indicate to the engine-drivers whether they applied to an up line or to a down line, to a main line or to a branch line. As the speed of the trains increased, and longer distances were required for stopping them, the signals were raised, and auxiliary or distant signals, worked by wires from a distance, came into use; and these, again, were sometimes distinguished by their forms from the home signals, when both were used; and in many cases distant signals were used without home signals. The home signals were worked by means of handles on the posts; the distant signals of levers on the ground, in what were considered convenient situations; and the points were worked by levers also on the ground, but scattered about, opposite to them, and frequently between the lines of rails. By degrees stations and junctions became more complicated, and the points and signals increased in number, and were at greater distances from one another. The signalmen sometimes had to leave their signal-levers, for the purpose of working points more or less distant from them, and occasionally at the opposite sides of lines of rails, which might be occupied by trains; and sometimes the points were worked by one man and the signals by another. But the mistakes, misunderstandings, and accidents which resulted from such conditions,—under which a signalman either himself omitted to work his points and signals in harmony, or signalled forward a train for one direction whilst a pointsman set the points for another direction,—led naturally to the concentration of the signal and point levers in or around the signal cabins; and, to afford a better view to the signalmen over passing trains, wagons in sidings, or other obstructions, the cabins were raised to a greater or less height above the ground, and placed in convenient situations, according to local circumstances. But even then, when the control was more conveniently placed in the hands of one man, there was still, as the levers in or near a cabin became more numerous, a liability to mistake, from the signalman pulling over a wrong lever; or the levers were fastened over by blocks of wood which the signalman forgot to remove; and, to prevent such mistakes, and serious accidents resulting from them, it became further necessary to interlock the levers with one another.

This important improvement was suggested, as being probably feasible, by Colonel Yolland, in a report dated January, 1856, on a collision which occurred on the 7th December, 1855, at the Bricklayers' Arms Junction on the North Kent Railway. It was patented by Mr. Saxby in 1856, and it made gradual progress between 1856 and 1860. By 1860 many further improve-

ments had been made by different persons, and the inspecting officers of the Board of Trade began to insist on the use of locking apparatus at the junctions of new branches with existing lines. The principle was also carried out in that year at the signal cabin at the entrance to the Victoria Station. In January, 1862, the author made the following, besides other recommendations, in reporting on a collision at the Walton Junction, near Warrington, on the main line of the London and North-Western Railway, on the first of that month:

"The points should be free to move when the signals are at "danger." The signalman should be unable to lower his signal for any train to pass until he has first set his points right for that train. After having lowered his signal for a train to pass, he should not be able so to turn his points in the wrong direction for that train as to cause a collision; and he should not be able to make any mistake in the working of his signals that can lead to a collision between any two trains. These improvements will necessarily lead to some alterations in the cabin itself, and the opportunities will be afforded in carrying them out of giving the signalman larger windows, that he may have a better view in each direction, and of providing him with telegraphic instruments and telegraphic communications, by means of which he may at least be warned of the approach of the trains upon the different lines which are under his control. This being an arduous and important post, and one at which considerable complication, and a very heavy traffic over two junctions are combined, I think it would be wise to employ three men to do the duty, and thus to reduce the periods of labor from twelve hours to eight for each man."

Taking a simple case of a double junction between a branch line and a main line, with the main line to the right, the branch line to the left, and the down line running north, there are several modes in which accidents may occur. A down main line, or a down branch line train may find the facing points set in the wrong direction, or partially open; or the signalman may split a train, as it is called, by shifting the points when it is passing through them. A branch line up train may run through a main line down train, or a main line down train may run through a branch line up train; or their engines may meet at the diamond crossing; or there may be collisions under different conditions between main line up and branch line up trains at the fouling point of the up lines; or the leading points may lie in the wrong direction on the approach of a train on either of those lines; or a train which is being shunted back from the up main to the up branch line may be met by a down main line train at the diamond crossing. By the application of locking and other apparatus it is possible to prevent nearly all of these accidents from occurring, in the ordinary way of working, in consequence of any mistake of the signalman. Conflict between signals, and conflict between points and signals, may alike be avoided; and a good combination of locking-bar and bolt may be made to insure that the facing-points are completely over before the proper signal is lowered, and may also prevent them from being moved during the passage of a train. It is, of course, impossible to provide against all the contingencies which may arise—such as, in certain cases, against the absolute neglect of engine-drivers to pay attention to the signals made to them; or such as a signalman, when two trains are running towards a junction at one time, setting his points and lowering his signals first for one of them, and then altering them and preparing for the second train, without allowing time for the first train to stop short of the junction. But provision may be made, and is made to some extent, even for the contingency of an engine-driver neglecting to obey signals. For instance, by making (in the example before referred to) the facing-points of the junction lead, as it is called, the trailing-points—that is to say, by so interlocking the levers that the former must be pulled over before the latter—it may be provided that any engine-driver approaching on the down line is necessarily turned along the branch down line, clear of the diamond crossing, when the points and signals are right for branch up-line trains to pass over that crossing, or when a train is being shunted back over it. There is, however, no means of providing against accidents from engine-drivers neglecting to obey signals on the branch up line, either when a main line down train has entered the facing-points, or when a main line up train is approaching the junction from the opposite direction.

In more complicated situations, when there are cross-over-roads between the

main lines or branch lines, or both, and through-crossings, and sidings connected at different points with the passenger lines, or where passenger lines are more numerous, and are connected at various points with goods lines and with one another, then the locking system becomes more complicated. But it is then, also, of still greater utility in securing the traffic from accidents, which become otherwise more likely to occur in consequence of mistakes on the part of signalmen. The same principles are applicable, but each case forms a problem in itself, to be carefully worked out according to its own circumstances; the objects being to give the signalman complete control over the traffic in every direction; to prevent him mechanically, as far as is possible, from making mistakes which may lead to accident; and to afford him the means of exhibiting a distinct indication to an engine-driver proceeding, or waiting to proceed, in any given direction. The control of the signalman is rendered more perfect by the addition of blind-sidings, so as to provide safety-points—where such are not in the laying out of the yard or lines otherwise available—to goods lines or sidings near their junctions with the passenger lines. These safety-points serve alike to prevent wagons from being blown out, or inadvertently run out or pushed out, and to prevent an engine-driver from proceeding against signals, and endangering the traffic on the passenger lines; but the levers of the safety-points require to be worked from the cabins, and to be properly interlocked with the other levers in the cabins.

Other devices, or provisions for enabling the signalmen better to perform their duties, may be mentioned; such as the system of slotting, as it has come to be termed, the connections of a signal, so that the arm of it may be raised to "danger" by a signalman in either of two neighboring cabins, but can only be lowered to "clear" by the joint action of the signalmen in both the cabins; the application of repeaters of various descriptions, either to inform the signalmen of the working of any signals which may be out of their sight, or to afford a more distinct indication, where such is required, to the engine-drivers; the means of information by telegraph as to when trains may be expected; clocks to furnish the correct time; register-books, in which to record the telegraph-signalling and passing of trains, so as to secure the regular performance of the duties, and to provide a check on the working of the signalman in any one cabin by the working of the signalmen in cabins on either side of it. But there are objections in the ordinary way to an overlap of the signals worked from one cabin by the signals worked from another cabin, as involving a liability to deceive the engine-drivers; and it is important to afford the means of all necessary communications between the signalmen, that they may not be working at cross purposes, and to deprive them of all excuse for making unauthorized signals on bells or block instruments to one another. Private signals or systems of inter-communication have frequently led to misunderstanding and accident. The selection and regular training of fit men for the performance of such duties; the employment of responsible inspectors for constant supervision, and the preservation of rigid discipline; the command of a sufficient number of relieving men, to take Sunday duty and to replace signalmen absent from sickness or otherwise; and the maintenance in high condition of the whole of the apparatus, are matters of obvious importance; but experience has shown that it is by no means unnecessary to refer to them.

When these desiderata are all properly worked out, and carried out in practice, great simplicity in working is obtained. Each signalman has control over his position, and is in a great measure prevented from making mistakes which may lead to accidents. The engine-drivers have in every case distinct indications to guide them, and are also, in many cases, prevented from causing accidents, even if they neglect to obey signals. The dangers of facing-points are for the most part obviated. Under such arrangements, engines and trains may be turned in and out and across one another with marvellous rapidity and facility, and in a way that would be impossible without the protection that they afford. The more numerous and complicated the lines, the sidings, and the crossings to be worked, the more indispensable does such apparatus become; and it is then, frequently, a means of considerable economy in the number of men employed, as well as a means of avoiding much sacrifice of life and limb to running pointsmen, yardmen, and shunters, whose services are to a great extent dispensed with. The simplicity in work-

ing thus obtained is not, however, apparent at first sight to the uninitiated, who see only an array of levers, and are not aware of the way in which they are named and numbered for the guidance of the signalman; each signal-lever bearing the number of any point or other lever that requires to be moved before it can be pulled over, and being also described as to its own particular purpose on a brass plate or otherwise. And it is not yet understood or appreciated in many cases by experienced railway officers who have not devoted much attention to this special branch of railway working. The comparative simplicity of the system will be best understood by an examination, and by watching the working, of any complicated stations or junctions at which it has not yet been applied; and it may to some extent be conceived by remembering what the confusion and complication in working would be if these levers were of all sorts, sizes, and shapes, scattered about in various situations, worked by different men, and independently of one another. An idea of the way in which confusion may be avoided will also be formed by comparison with the elementary principle of another system once in force, and much persisted in as being correct, on one of the great railways of this country. A signal-post was placed at a junction with one arm on it applicable to two conflicting lines of railway. It was an eminently simple arrangement in more than one sense. But it had the disadvantage that when two engine-drivers approached a junction from two directions at the same time, and when, seeing the one semaphore-arm lowered, or a hand-signal waved, each thought it was intended for him, they advanced together towards the junction, and then could not avoid in some cases running into each other. It was only after repeated collisions from this cause, and consequent remonstrances from the Board of Trade, that this arrangement, simple in construction, but which undoubtedly led to confusion in working, was at length abandoned. A simpler arrangement still, as far as construction is concerned, is a mere hand-flag, or hand-lamp, or the arm of a signalman; but, unfortunately, they are not well seen, and they are liable to be, as they have too often been, overlooked or wrongly interpreted, especially when signals require to be exhibited in several directions at one time; and thus it becomes necessary for true simplicity in working to employ what are sometimes complained of as complications, in the way of posts, levers, rods, cranks, arms, lamps, and glasses; and to provide a separate signal tor every purpose for which a signal is really required, to enable a distinct indication in every case to be exhibited by a signalman and received by an engine-driver.

(To be continued.)

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—April 15, 1874.—A stated meeting was held at 8 o'clock P. M.

Communications from Hon. William J. McAlpine, giving a record of "Experiments on Mixtures of Mortars and Concretes," and upon the power of earth to sustain foundations, were read and briefly discussed.

The death, on April 1st, of John B. Rogers, C. E., late of St. Louis, Mo., and Member of the Society, was announced; and Messrs. C. Shaler Smith, Thomas J. Whitman, and Walter Katté, were appointed a committee to present a fit memorial of the deceased.

A communication from Prof. Henry Morton, President of the Stevens Institute of Technology, relating to the founding of a "Testing Laboratory," for making complete and impartial tests of the characteristics, value and strength of materials used in the arts, was presented, and referred for consideration and report to a committee consisting of Messrs. Octave Chanute, Albert P. Boller, and Richard H. Buel.

A paper by Col. W. Milnor Roberts, in review of Revy's "Hydraulics of Great Rivers," was read, and the subject as referring to the improvement of the mouth of the Mississippi, discussed by Messrs. Chanute, Thurston, and others.

May 6, 1874.—A regular meeting was held at 1 o'clock P. M.

The vote on admission to membership was canvassed, and the following declared elected: Members, Charles E. Emery, M. E., of New York; John A. Judson, C. E., of Newport, R. I.; Otho E. Michaelis, Capt. Ordnance, U. S. A., of Pittsburgh, Pa.; Robert M. Newman, C. E., of New York, and Edward S. Philbrick, C. E., of Boston, Mass., and Junior, Russell H. Curtis, C. E., of New York. The death, on April 16th, of Jonathan Camp, Jr., C. E., late of Jersey City, N. J., and Member of the Society, was announced, and Messrs. Andrew J. Post, Charles Macdonald, and Arthur Speilmann, were appointed a committee to present a fit memorial of the deceased.

A paper by J. James R. Croes, C. E., on the "Flow of the West Branch of the Croton River," and referring to the relation between the flow and the rainfall, was read. Remarks on certain views contained in Revy's "Hydraulics of Great Rivers," and on the proposed improvements of the mouth of the Mississippi, were made by Col. W. Milnor Roberts and Gen. Theodore G. Ellis.

A report from the committee appointed February 18th, to consider the "Memorial of the American Metrological Society," was read, discussed and laid on the table; and one from the committee ap-

pointed February 4th, to which was referred a communication asking the Society to declare what should be the course of instruction in schools and colleges, for students of engineering, was read and adopted.

May 4, 1874.—A stated meeting of the Board of Direction was held at 2 o'clock P. M.

Proposals for admission to the Society were considered, and the President, Secretary, and Chairman of Committee on Finance were appointed a Committee on Applications, to whom all proposals for membership shall be referred for examination and report to the Board with such recommendations as the committee may deem proper.

The Treasurer presented his semi-annual report on the finances of the Society, which was accepted, and referred to the Committee on Finance.

The committee, appointed April 1st, to consider the expediency of a change in location of the rooms of the Society, presented a report which was accepted.

Messrs. John Bogart, W. Milnor Roberts, Charles Macdonald, Francis Collingwood, and Theodore Weston, were made a Committee on Rooms, to confer with kindred associations in New York, select chambers in a central location after the existing lease expires, and report to the Board. Members opposed to a change of place are requested to state their reasons therefor.

IRON AND STEEL INSTITUTE OF GREAT BRITAIN.—This Association has just concluded its spring meeting.

The leading topics presented were as follows:

The first paper read was by Mr. A. Smith, "On the Shaping and Finishing of Iron and other Metals by Solid Emery Wheels, and on Machinery Specially Designed for such Purposes." It was observed that the general rise in the price of labor and materials had caused the attention of manufacturers to be directed to the use of solid emery wheels as great labor-saving tools.

The "Berryman Feed-Water Heater" was described in the paper which was read by the gentleman whose name the apparatus bears. He explained that a feed-water heater is an important adjunct to engines and boilers where it is an object to economize fuel by utilizing the heat remaining in the exhaust steam after it leaves the engine.

The "Pernot Rotary Puddling Furnace" was described in a paper by Mr. Petin, of Paris, read by Mr. D. Forbes, the Foreign Secretary. It was stated that at first the process did not seem to promise much, but it is now unsurpassed by any in use in France.

The paper on the "Spathic Iron Ore Districts of Europe," by Mr. Charles Smith, of Barrow, which was read by the General Secretary, is of especial interest at the present time, because it is the raw material from which spiegeleisen is most conveniently produced, and spiegeleisen is an essential element in the Bessemer process for the manufacture of steel. Three or four years since it became a question whether it would be possible to utilize, for Bessemer steel purposes, the largely increasing make of suitable pig iron, in consequence of the small quantity of spiegeleisen brought into the market, most of which was derived from Rhenish Prussia. It was, therefore, most important to know if the existing production could be increased, and if it were possible to obtain additional supplies from fresh districts.

"The Manufacture and Use of Spiegeleisen" was the subject of the next paper, by George J. Snelus, who stated that spiegeleisen was of but small value formerly, but in course of time its use in the Bessemer process brought it into prominence, and raised its value. It was first made and used at the Ebbw Vale Works, and in time, as the market for it increased, its manufacture extended to other parts, and it had now become an important and an established industry.

"The Condition in which Silicon exists in Pig-Iron" was then discussed, in a paper by Mr. E. Handfield Morton, who said he had been induced to make a few experiments by noticing that silica was obtained in an insoluble residue when pig-iron, containing a large quantity of silicon, was dissolved by diluting sulphuric acid *in vacuo*, instead of silicon. This fact pointed out that the theory of silicon being intimately mixed with pig-iron was untenable.

The last paper read was that on "Coupling Power for Rolling Mills," by Messrs. F. N. Varley and Furness, who described a means for controlling or reversing mills which received their power from a continuously and uniformly driven shaft, where the fly-wheel picked up the accumulated momentum, and the shaft to all practical purposes might be considered to be driven at a uniform rate. A means for quickly arresting a rotation body might be obtained by altering the direction of the force so as to avoid a sudden shock. The accomplishment of this idea was explained by diagrams, and it was shown that in the case of any sudden strain on the wheel the shaft and attachments would not receive the shock, and that the force of the blow would be spread over a period of time sufficient to destroy its intensity.

IRON AND STEEL NOTES.

STATISTICS OF THE IRON AND METAL TRADES.—In the introduction to the new edition of Messrs. Kelly & Co.'s "Iron and Metal Trades Directory," there have been collected a number of figures indicating impressively the vast extent and importance of these industries, which furnish employment directly to nearly a million and a half of our population.

Turning to the metal with which we ourselves are more particularly identified, we find that the total quantity of iron ore raised in 1872 from 266 mines was 15,584,857 tons, and, adding the foreign ores imported, 16,539,889 tons of iron ore were smelted in Great Britain. In the same year there were made in England, 4,594,614 tons of iron; in Wales, 1,057,315; and in Scotland, 1,090,000; the number of furnaces employed in each country being respectively 450, 122, and 130; 276 mills and forges were also returned as at work, having 7,133 puddling furnaces and 1,015 rolling mills, together with nineteen works employing 91 Bessemer converters. Besides the iron worked up in our own manufactures, nearly three millions of tons, valued at about £38,000,000, were exported in 1872. From 1850 to 1870, the declared value of British produce and manufactures, mineral and

metallic, rose from about fourteen millions sterling to forty-three and a half, the iron and steel in the last-named year being valued at £21,675,218, or four times what it was twenty years previously; machinery and mill-work to nearly six millions; and hardware and cutlery to nearly four. The value of coals, coke, and patent fuel exported in the same period increased from £1,284,224 to £5,638,371. In 1873, iron had risen still farther to £37,779,586; coal, etc., to £13,205,618; hardware and cutlery, to close upon five millions; the metallic exports for that year reaching a grand total of £75,107,840, nearly thirty-two millions sterling over those of 1870. Tin, terne, and black plates form a comparatively large item in our metallic exports, amounting in 1873 to 120,468 tons, valued at £3,952,841. The extent and importance of our coal mines may be judged of from the following figures: The number of collieries in the United Kingdom is upwards of 3,000, from which, in 1872, there were raised 123,497,316 tons, valued at £46,311,143. Of this there was used in making pig-iron, 17,211,729 tons; in the metallurgies, 371,605; exported to foreign countries, 13,187,494 tons. In the following year about 15,000,000 tons were shipped abroad, their declared value being £13,205,618. Of the workers in metal in the United Kingdom 376,783 are miners; 174,704 workers, etc., on arms; 779,838 workers and dealers in minerals and metals; and 16,742 machine and tool-makers.

Much of the manufactured iron retained in the country consists of machinery. The estimate for 1870, which is believed to be considerably understated, was that there were then in the United Kingdom 6,708 textile factories, running over forty-five million spindles and nearly six hundred thousand power-looms, giving employment to over a million of the population—nearly double the number employed in 1855.

The railways also take up a very considerable amount of home-made iron, and both steel and iron rails and engines are largely exported to the colonies and foreign countries. The increase in the mileage of railways in the United Kingdom between 1850 and 1873 was 9,000 miles—well on to double—and the number of locomotives, 9,503. In India and the Colonies there are upwards of 12,300 miles open. A large quantity of iron and other metallic material is used in telegraph construction. There are 3,374 miles of submerged cable wire in the United Kingdom, 83,408 miles of public telegraph wire, and 4,311 miles of private wire. There are in India and the British Colonies upwards of 65,000 miles of wire fixed, and much of the submarine cable in all parts of the world is manufactured in England. There are also over 60 wire-rope manufactories in the kingdom, this fabric being, besides its employment in telegraphy, more and more extensively used as a substitute for vegetable fibre.

Another new and increasing department of iron-work is the manufacture of agricultural implements. In England and Wales alone there are 3,617 agricultural implement makers, and from 30,000 to 40,000 steam-engines employed in farming operations.

The iron and wooden steamships which plough the main almost rival in number the sea-birds which float on or fly over it. According to the latest official returns, there were registered as belonging to the United Kingdom in 1873, 3,853 iron steam-vessels, of 1,711,767 aggregate tonnage. In the same year no fewer than 63,000 British steam-vessels of both kinds, measuring 50,388,055 tons, entered with cargoes at ports in the United Kingdom from foreign countries and the coasting trade—a marvellous increase from the 104,680 tons in 1850.

PHOSPHORUS IN BESSEMER PIG.—Mr. Platt asks in the "Engineering and Mining Journal" the amounts of phosphorus and other ingredients allowable in Bessemer pig. The amount of each depends, to some extent, on the amounts of the others. Either carbon, or some metal, such as manganese or silicon, is necessary to give body to steel, and these substances may replace one another. If the steel has 0.15 of phosphorus, and an average amount of other ingredients, it will be made brittle by 0.30 of carbon. But if it contains but 0.05 of phosphorus, other things being equal, it will not be made brittle by 0.75 of carbon. Phosphorus and silicon, above, say 0.10 per cent., produce a decided tendency to cold-shortness. Manganese, up to 0.75, does not, of itself, appear to impair toughness, although so large a percentage cannot be allowed in rail steel containing 0.10 of phosphorus, 0.10 of silicon, and 0.30 of carbon. I am not attempting to give absolute formulæ, nor even a general rule for the synthesis of steel. We have too few analyses of mechanically tested specimens to warrant any such close conclusions. I am simply illustrating the tendency of these outside substances to replace one another as body-givers to steel.

Therefore, equally good Bessemer pig-irons may vary considerably; if they are rich in phosphorus they must be poor in other cold-shortening. If they are rich in copper they must be poor in sulphur and other red-shortening. The average percentage of phosphorus in twenty-seven Lake Superior pig-irons, the analyses of which are before me, is 0.13. Most of these are suitable for Bessemerising, and I think Lake Superior Bessemer pig averages about 0.12, but it is quite pure otherwise, and admits of being well-blown, *i. e.*, thoroughly decarburized, so that the resulting steel is as tough as any in the market. As much phosphorus as this, in the English Cumberland irons, and in some American irons, would tend to produce brittleness. The amount of phosphorus allowable also depends upon the amount of carbon restored by the recarburizer. Of common spiegeleisen, having 10 per cent. of manganese and 5 per cent. of carbon, some 8 per cent. must be put into the blown metal, in order to introduce manganese enough to cure red-shortness, and a good deal of carbon is thus necessarily introduced. Eight per cent. of spiegel added to a well-blown iron will give 0.30 to 0.40 of carbon in the steel. But if a ferro-manganese having, say 60 or 70 per cent. of manganese, and only 2 or 3 per cent. of carbon, is employed, so little of it is needed to furnish the requisite manganese that the accompanying addition of carbon is very slight; hence more phosphorus may be present. This is the basis of the Tessié du Motay process in use at Terrenoire, France. Silicon in Bessemer pig averages about 2½ per cent. As much as this is needed to produce sufficient heat. Some mineral coal pigs contain 4 per cent. and over; some charcoal pigs have but ½ per cent. of silicon.

The *mixture* used should have 2 to 3 per cent. Sulphur in Lake Superior Bessemer pig rarely runs above 0.02; in Missouri pig, rarely above 0.01. Sulphur in English Bessemer pig averages about 0.10. Two or three per cent. of manganese would be valuable as a purifier, though too much would make the blowing difficult, and it would not take the place of the spiegel. Of other metals there is not likely to be enough to do much good or harm, in such American ores as have been developed.—A. L. HOLLEY.

FRENCH IRON STATISTICS FOR 1873. The total make of pig iron in France in 1873 was 1,381,000 tons, being only 17,000 tons less than that of 1869, the largest that was ever reached having been 1,398,000. Compared with 1872, the increase has not been less than 200,695 tons. The total output of manufactured iron in 1873 amounted to 906,745 tons as against 883,079 tons in 1872, showing an increase of 23,666 tons. There is a falling off, however, of 126,000 tons compared with the extraordinary make of 1869. The total production of steel during the year reached 167,677 tons against 138,552 tons in 1872, or an increase of 29,125 tons. Since 1867 the steel manufacture in France has increased tenfold, and the upward movement is likely to continue. The sum total of iron and steel rails which the sundry railway companies ordered from the home works during 1873 is 188,815 tons, of which 124,717 tons were of iron and 64,098 tons of steel. The Paris-Lyon-Mediterranean railway alone consumed during the year 32,500 tons of steel rails: the Nord, 14,625 tons; the West, 9,871 tons. Compared with 1872, the consumption of iron rails increased 20,750 tons, and that of steel rails 11,903 tons. Adding to the above figures 8,544 tons of iron rails and 2,000 tons of steel rails imported during the year, we find for all the French railways together a consumption of 133,261 tons of iron rails, and 66,098 tons of steel rails, or a grand total of 199,359 tons.—*Bulletin du Comité des Forges de France.*

RAILWAY NOTES.

GRANTHAM'S STEAM CAR FOR TRAMWAYS.—An experimental trial of a steam tramway car, which appears likely to satisfy all the material requirements of such a conveyance, was made recently in a field near the West Brompton Station of the District Railway. The inventor, Mr. John Grantham, C. E., besides his special qualifications, has had much experience in such matters both abroad and at home. Among other things, he personally laid out the Copenhagen Tramway, a work very difficult of execution. Since small steam-engines have been brought into general use, various improvements have been introduced, and these and others of his own suggestion Mr. Grantham has combined and applied to the use of the modern tramway system. In carrying out the practical details of a tram car also, it is to be observed that a short wheel base is required to enable it freely to pass the curves, while the car itself must be of great length to accommodate a sufficient number of passengers. This involves the necessity of placing the weight of the machinery in the centre. Steam cars having the machinery at the ends have been tried, but the arrangement is destructive of all the requirements above described. A long wheel base, however, has its advantages in keeping the car steady. To accomplish this, and still to ease the motion at the sharp curves, Mr. Grantham has adopted the bogie system, now prevalent on many railways. This arrangement has also important advantages of another kind. By a simple addition to the bogie frame, he has been able to introduce a plan for guiding the car, so that no movable switches are required at the sidings—a point of great importance on tramways. It also gives the power to leave the rails when an obstruction occurs, or to get on them again when the car is accidentally thrown off.

The car used at the trial, on Saturday, weighed some four or five tons, and resembled in shape those which it is intended to supersede. The engines, which are almost totally hidden from view when the car is in motion, are placed in the middle of the vehicle, on either side. The cylinders are 4 inches in diameter, with a 10-inch stroke, worked direct on the crank axle. Fuel is now supplied by hand, but we were informed that future cars will be furnished with an automatic feeder. It is calculated that the quantity of coal which would be consumed in a twelve-hours' running would be about 5 cwt. The car can be worked from either end, the driver having simply to shift the lever from one end to the other. Several trips at various speeds, from seven to about fifteen miles an hour, were made along a line laid on the side of a grass field, and extending for about a quarter of a mile. Nothwithstanding the unfavorable nature of the ground, the runs were made with almost perfect smoothness and steadiness. There was no noise, save the rattle of the wheels, and neither smoke nor steam was visible. Inside there was neither heat nor smell from the machinery. While running at seven miles an hour, the car was brought to a standstill, by means of a foot-brake, at about half its own length. It is intended to use for this purpose a light hydraulic brake, which will be applied to the axles, and a guard or cow-catcher will be attached to each end of the cars.

One of the most important features in connection with Mr. Grantham's invention is that whereby the driver has such a command over the forewheel that on approaching a junction, instead of having, as in the case of horses, to pull the horses over, or to be dependent on a switch boy, he can, by the simple application of a lever, divert the course of the car. Future cars will have the advantage of that experience which has been the outcome of the construction of the present one. Bells which keep constantly ringing by the aid of machinery when the car is in motion, will also be placed at each end of the car. The small quantity of steam now occasionally visible when the car is running continuously will also, we understand, be considerably diminished.

Mr. Grantham contends that it is a narrow view to suppose that improved tramways will interfere with railways. It may fairly be expected that they will become feeders rather than rivals. In some localities their interests may clash, but the reverse will be the rule. Extended as is the net of the railways that now intersect this country, many small towns and villages are suffering for want of them, and are being left behind in the rapidly-increasing facilities which large towns

and even small ones, which happen to be in the railway routes, are receiving. The costly railway and its heavy engines and plant require a traffic which few small towns or villages can support, while the horse omnibus and the carrier's cart, over rough roads, are the only means of communication for the people. A London tramway car at present requires ten to twelve horses, and as each horse costs about £60 per annum, the total expense of horses alone is from £600 to £700, independent of the wages of the driver, conductor, and of the car itself By using steam-engines as substitutes for horses, the experiments with the present car show the following results:—To work the car for fourteen hours requires 5 cwt. of coke and coal mixed, which, at the average cost of fuel in various places, will amount to 5s. to 7s. 6d. a day; add to this the extra wages to the engine-driver, the wear and tear, and sundries, about equal to the cost of fuel, leaving an annual expenditure of about £250, or a saving of about £400 for each car.—*Iron.*

ENGINEERING STRUCTURES.

THE EAST RIVER BRIDGE. This important structure which has remained as the workmen left it in December last, is again to be pushed forward with activity. The New York tower is 123, and the Brooklyn tower 222 ft. above high water. The latter will doubtless be completed this year. Work on the Brooklyn anchorage will also be at once resumed.

THE WILLIAMSBURG DAM. *Report of the Committee Appointed by the Society to Investigate the Causes of its Failure—Chairman of Committee, James B. Francis, of Lowell, Mass.* The dam is between 500 and 600 ft. long, and about 43 ft. high at the highest point near the centre, diminishing to nothing at the ends, forming, when filled, a reservoir in the valley above it of an area of 111 acres, with an average depth of about 20 ft. At the time of the failure the water was about 4 ft. below the top of the embankment, not an unusual height at this season, and within a few months it has been at least a foot higher. The failure took place between 7 and 8 o'clock on the morning of May 16, when probably ¾ of the contents of the reservoir escaped in about 20 minutes, or at the rate of about 60 cubic ft. per second, destroying in its course through the steep and narrow valley below 143 lives, and property to the amount of more than $1,000,000. The dam consists of an earthen embankment with a longitudinal wall of stone and cement through its centre, a waste-way 33 ft. wide in the natural ground at one end of the embankment, and a 16 in. pipe through the embankment and wall at the lowest point for the discharge of water as wanted for use at the mills below.

Two or three plans for a dam at this point were prepared and rejected by the Company on the ground of their cost; one of them by the late Mr. Stewart S. Chase, a member of the Society. The plan adopted, or rather the specifications, for it does not appear that any plan was drawn, were prepared by Mr. Lucius Fenn, civil engineer, now of New Britain, Conn., who, according to the evidence reported to have been given by him at the Coroner's inquest, claims to have written them under the direction of the Direction.

The Main Reliance on the Wall.—On a personal examination of the site and remains of the dam, we find that the bottom is a very compact hard-pan overlaid by about two feet of coarse gravel and a few inches of soil. The hard-pan appears to be impervious to water, or as nearly so as any soil can well be, and at the breach is but slightly washed, except near the discharge pipe, where there is a gully several feet in depth, which may, however, be due in part to the former action of the brook. The gravel overlying the hard-pan is washed and porous. A small spring is now to be seen coming out from under the remains of the embankment above the centre wall, which is evidently superficial, and from the gravel. The embankment is formed of gravel similar to that above described, but containing a little loam. It was taken from the side of the hill just above the dam. It has scarcely anything binding in its character, and is not capable of being made into a puddle which would stop the percolation of water. From the character of the bottom, and the material available for the embankment, it is obvious that the main reliance for retaining the water must be in the cement wall and the complete union of its base with the hard-pan; the main office of the embankment being to support and protect the wall. By the specifications nothing more was required than "trenches 3 ft. deep, or of sufficient depth to give a firm, hard and secure bottom for the masonry to rest upon, and which will not allow the masonry to settle;" the intention evidently being only to secure a foundation sufficient to prevent settling, as if for a building or bridge abutment, totally ignoring the vital function of the cement wall by not adopting means to prevent the passage of water under it.

No Security even if built according to Specifications.—It was undoubtedly expected that the embankment would prevent the water in the reservoir from reaching the base of the wall, and to make this sure the specifications provide "the earth to be placed in thin layers, wet and tamped, or beaten with a maul for a distance of 5 ft. each side of the entire wall." Supposing this to have been done as perfectly as possible with the material, what security could it give against a pressure of 40 ft. head of water?

The remainder of the embankment on the upstream side, being built in layers of 5 ft. in thickness of this porous material, could evidently not be depended on to supply the deficiency. The water in the reservoir, we are informed, is always clear, as might be inferred from the character of the water-shed, which, as far as observed, consists of steep, rocky pasture and woodland. There would consequently be very little deposit of sediment on the embankment, which might otherwise in time have rendered it water-tight.

The specifications are also defective in providing for slopes of only 1½ to 1. They should be at least 2 to 1 on the outside, and 2½ to 1 on the inside. Another defect is in providing for a height of the embankment only 2 ft. above the top of the centre wall. The height should be sufficient to protect the wall completely from frost, which in this climate requires 5 ft. of earth at least. If the earth becomes frozen to the wall it is liable to

heave or fracture it. We give no particular description of the discharge pipe and waste-way, as the failure in the dam appears to be wholly unconnected with them.

In the construction of the work by the contractors it appears that there was no sufficient inspection, so peculiarly important in a work of this description, and during great part of the time none at all, except by the Directors of the Company, or their Building Committee during their occasional visits. The remains of the dam indicate defects of workmanship of the grossest character. The bottom of the wall does not in all cases even rest upon the hard-pan. It was in evidence at the inquest that the wall was laid up dry, and grouted 5 ft. high at a time. The grouting has not completely filled the cavities, and the quality of the mortar is, some of it, very bad, as might be expected from this mode of building. The soil and porous gravel were only partially removed from the base of the embankment for 30 ft. on each side of the centre wall, as required by the specifications.

The Work not to be Justified on Engineering Principles.—It is probably not possible to ascertain with certainty the immediate cause of the failure, but from the evidence obtained we can come to no other conclusion than that the water found its way under the wall at a point about 100 ft. from the discharge pipe, causing a slip in the embankment on the down stream side of the centre wall, which, being then unsupported, yielded to the pressure on the upper side, and, falling over, made a breach, which was rapidly enlarged by the washing away of the embankment and the fall of the other parts of the wall.

It may be asked, if this was the immediate cause, why did it not happen before when the reservoir was at a higher level? The answer, we think, would be, that there has been a gradual working out of the gravel under and near the wall, and loose places or cavities formed, which, when they had attained a certain development, would suddenly lead to their failure.

The Committee understand that the principal object of their appointment to report on this matter was to study it as an engineering work, it being well understood that usually more is to be learned from one failure than many successes; but it is obvious that this cannot be called an engineering work. Its engineer, or person calling himself such, can be held responsible for either its design or execution. According to the evidence reported, it must be considered as the work of non-professional persons. This being the case, the Committee do not think it devolves upon them or on the Society to criticise its design or execution. The causes of a failure attended with such disastrous consequences cannot fail to be interesting to the members of the Society, and we have endeavored to point them out.

In connection with this report, W. E. Worthen of New York exhibited a model of the broken dam, and explained in brief terms the manner in which the break was first discovered, and the subsequent sliding away of the wall. He said that it was far from being his opinion that persons could build reservoirs by intuition. A thorough knowledge of the power of water as well as the strength of masonry was required, and this necessitated study. The employment of men who did not understand water was not judicious, to say the very least; and those who employed them have found to their cost that it was an unwise economy.

ORDNANCE AND NAVAL.

PRESERVATION OF THE IRONWORK OF THE HULLS OF COMPOSITE SHIPS.—The Lords Commissioners of the Admiralty have issued a circular, No. 31 S, specifying the duties of dockyard officers and of officers in commissioned ships of composite build, with reference to the preservation of their iron frames, etc. It directs dockyard officers to see that (*a*) bilge pipes are not of copper, brass, or lead, except those belonging to the engines, which are necessarily of brass or copper, and that such are to be painted and clothed with canvas; that (*b*) parts necessarily inaccessible are to be specially pointed out to the officers of the ship; (*c*) the frames to the turn of the bilge covered with cement or suitable composition, but painted elsewhere; (*d*) the cement to be examined wherever accessible when the ship is in dockyard hands; (*e*) and a thorough examination every three years; (*f*) including in this all dockyard craft or other vessels belonging to the port. It directs the officers of the reserve and of commissioned ships that (*a*) the chief engineer and carpenter are to examine the ironwork every six months, and make a joint report; (*b*) any decay or want of cement or paint to be made good, (*c*) and the Secretary of the Admiralty informed of what was seen and done. Examinations are to be thorough (*d*) every three years, and (*e*) a special report to be made thereon, if not at a royal dockyard. This circular practically provides for composite ships what circulars 28 of 1872, and 22 of 1873, provided for iron ships and iron ships wood-cased.—*Engineering.*

BOOK NOTICES.

THE UNIVERSAL REVIEW OF MINING, METALLURGY, PUBLIC WORKS, SCIENCE, AND THE INDUSTRIAL ARTS. Being the English edition of Revue Universelle des Mines, de la Metallurgie, etc. London: W. Richards Hutchings, 5 Bouverie street.

The first number of this work has now made its appearance, and in every respect fully justifies the high anticipations that had been formed of it. The contributors are all well known for their special acquirements in matters relating to mining, metallurgy, and cognate matters. They are associated with the central and other celebrated schools of Paris, and with the engineering branches of the chief industries of Liege, Charleroi, etc., in Belgium. We have read each article not only with profit but pleasure, and to those of our readers who desire scientific articles upon the subjects named above, which are free as possible from scientific technicalities, we recommend this work. We give below the contents for the number before us: I. Notes on Coke Ovens. H. Steel Rails, as used by the principal Railway Companies in France. III. Applied Ceemistry, as illustrated in the Vienna Exhibition, 1873. IV. The International Congress on Patents. V. On the Conditions of the Manufacture of Extra-Silicious Pig Iron in the Blast Furnace. VI. Notes on Work

Performed by Compressed Air. VII. Boring Machines, Worked by Compressed Air. VIII. The Economy of Fuel. IX. Notes on Experiments made by M. Lhoest, at Maestricht. X. Notes on Manufacture of Caoutchouc. XI. The Manufacture of Wrought and Cast Iron by Charcoal, in L'Entre Sambre-et-Meuse. XII. The Appendix ("Bulletin"). (1) On the Use of Steel Rails in Russia. (2) Lightning Conductors. (3) Tests of Steel. (4) Tariff of Import Duties to the Zollverein of Iron and Castings.—*American Manufacturer.*

A Conversation on Mines, etc., between a Father and Son. By Wm. Hopton. For sale by D. Van Nostrand. Price $1.50.

This is the fifth edition of this little book.

It affords, in a familiar style, an insight into the details of practical mining. The rudiments of mining surveying are elucidated in this much better than in more pretentious works.

Neither the typography nor the cuts are very attractive in appearance, but the value of the whole matter of the book to the young learner is unquestionable.

On the Origin and Metamorphoses of Insects. By Sir John Lubbock, Bart. London: For ale by D. Van Nostrand. Price $1.50.

This book seems of too small dimensions to treat adequately of so extensive a subject. The distinguished author, however, knows how to say much in a few words. A great number of cuts is always needed to illustrate such a topic as this, and the want is abundantly supplied; the separate figures average two to each page of descriptive text.

The subjects to which the separate chapters are devoted are:

I.—The Classification of Insects.

II.—The Influence of External Conditions on the Form and Structure of Larvæ.

III.—The Nature of Metamorphoses.

IV.—The Origin of Metamorphoses.

V.—The Origin of Insects.

The Science of Embankments. Van Nostrand, the publisher of the engineering profession, sends us one of his "Science Series," a little brochure on the "Designing and Construction of Storage Reservoirs," by Arthur Jacob, a Royal Engineer of considerable experience in India. In the East, reservoirs, or tanks as they are there called, are very common for the storage of water for irrigation; and now during the famine, when it is necessary to employ the people to keep them from starving, most of the work is directed to the construction of new tanks. The ancient reservoirs of the East put our modern civilization quite to shame, some of those in India having embankments 20 and 30 miles in length. Some of these have fallen into disuse on account of the expense of keeping them in repair; but there is one in Ceylon 15 miles long, with a wall of solid and matched masonry, buttressed with earth to a breadth of 100 ft. at the base and 40 ft. at the top. There is no sham about that, and because it was built by impressed and unpaid labor. Mr. Jacob's essay is written for the latitude of England, but does not seem to be made useless for us by the distance of his experiences. Earth and water are the same at the antipodes as here. First, as to the strain or pressure of water, he gives a rule which may interest the inexpert. The weight of water against a perpendicular wall is equal to the product of the area of a perpendicular section of the water, multiplied by the depth of the centre of gravity of the wall below the surface and by the weight of a unit of water. A perpendicular dam, 10 ft. high, and sustaining 10 ft. of water, sustains for every foot in length 3,125 lbs., this being the product of 10 sq. ft., the area of water, by 5 ft., the distance from the top to the centre of gravity of the wall, by 62½, the weight of a cubic foot of water.

But Mr. Jacob cautiously observes that "the principles that direct the design of embankments to retain water are not those that apply to calculations of the forces to be resisted or the means to overcome them, any more than breakwaters and harbor walls can be designed on mathematical principles." We come at once upon one principle, however, which was violated at Williamsburg. According to the statement of one of the proprietors, this reservoir was built with a slope on the inside of 45 deg., the slope at which earth out of water is stable. But in water a much greater slope is required, and as soon as this oversight was discovered, an attempt was made to remedy the difficulty by dumping in earth and stones. Mr. Jacob states that "earth, when subjected to the action of water, almost invariably loses a certain amount of its stability, and in most of the best existing examples the inside slope of the bank is either 3 to 1 or 2½ to 1"; that is, 3 ft. slope to 1 ft. perpendicular height, etc. He prescribes for the outside slope, 2 to 1 or 3 to 1. "The impermeability of earth is a matter that cannot be relied upon." He thus describes the best English embankments:—

"The practice adopted in the best English embankments has been to carry up the earthwork in layers of 2 or 3 ft. in thickness, and, at the same time, to construct in the centre of the bank a wall of well-puddled clay, the foundation of which is carried down for whatever depth may be necessary in order to reach an impermeable bed of earth or rock. It is not in all situations possible to procure earth exactly suitable and in sufficient quantity for the construction of an embankment, and consequently it is advisable to dispose the best part of the material—that is, the most retentive of water—in juxtaposition to the puddle-wall. Earth should not be removed from the bed of the reservoir, as a natural basin of clay may thus be irretrievably broken through. In specifying for the dimensions of the puddle-wall, a sound rule for adoption is that it shall have *a thickness of* 10 *ft.* at the top water-line, and increase in thickness to the surface of the ground at the rate of 1 in. on either side for every foot downward."

The author recurs to the Sheffield disaster in 1864, and to the irreconcilable differences of engineers regarding that work. In that case the bank was 95 ft. high, with a top width of 12 ft., and slopes of 2½ to 1. The puddle-wall was 16 ft. in width at the ground-line, and tapered to 4 ft. at the top. Mr. Jacob says, that the fault of this dam was the too great reliance upon the masonry, the earth being put in loosely. The presumption that 25,000 ft. in area of masonry was to be constructed without a flaw he regards as

reckless. He agrees with Stewart Chase and Mr Brigga, that the puddle is merely an accessory to arrest the damage of vermin burrowing in the earth, or the dissolving of soft spots in the earth itself. He finally places the only safety where the "Republican" has already placed it—in an impermeable lining of the reservoir embankment. "The most desirable as well as the most usual practice," he says, "is to pitch the whole of the inner face of an embankment with stone, carefully laid by hand. Neglect of this precaution has led to the destruction of many embankments, in other respects securely constructed."—*Springfield Republican.*

MODERN ENGINEERING.—A Lecture delivered before the American Institute. By WM. J. MCALPINE. New York: D. Van Nostrand. Price $1.50.

The above lecture has been widely published already in the scientific journals. It was delivered in December, 1868, and the edition published at that time has gradually become exhausted; hence this second edition. The relation of old science to the new is pleasantly portrayed, and the statistical facts, which are compactly presented, give substantial value to the lecture, and render it worth preserving.

The attempt to entertain a popular audience, and at the same time present truths that engineers could listen to with pleasure and profit, proved eminently successful.

THE CONSTRUCTION OF MILL-DAMS. Springfield, O.: For sale by D. Van Nostrand. Price $2.50.

This work consists largely of a series of articles published originally in "Leffel's Milling and Mechanical News." The degree of interest manifested in the original articles satisfied the publishers that a volume comprising the best obtainable information on the Structure of Dams would meet a public want.

The book is not put forward to advocate a theory, nor, indeed, to sound the praises of any particular engineers or builders, but to briefly and plainly describe the details of established works.

The text is illustrated by many cuts, which, without being of excellent quality, are sufficiently good for the purpose

THE DISTRIBUTION OF RAIN OVER THE BRITISH ISLES DURING THE YEAR 1872. Compiled by G. J. SYMONS, F. R. B. S. London: Edward Stanford. For sale by Van Nostrand. $2.50.

Meteorological reports never afford very lively reading, and but few readers consider them profitable. Such statistics have an undoubted value, however, and to quite a variety of inquirers.

Hydraulic engineers and agriculturists, who regard the drainage and storage of water with interest, look upon the records of past years with a practical eye, while the physicist, seeking for the development of a law, scans the figures to see if a cycle can be detected in the seeming irregularities.

The present report abounds in maps, and affords excellent suggestions to observers, which apply to all localities.

THE PHYSIOLOGY OF THE CIRCULATION IN PLANTS, IN THE LOWER ANIMALS, AND IN MAN. By J BELL PETTIGREW, F. R. S. London: For sale by D. Van Nostrand. Price $4.00.

The author says of his labor in preparing this volume: "I have endeavored to give a comprehensive account of the circulation, and the apparatus by which it is effected in Plants, in the Lower Animals, and in Man. I have discussed the subject in its totality, in the hope that those parts of the circulation which appeared obscure in the higher animals might be simplified by comparing them with similar parts in the lower animals and in plants. This mode of treatment involves details, but these, I trust, will be found also to add additional interest. I have introduced a large number of drawings in place of the diagrams originally employed in illustrating the course in order, in some measure, to efface the traces of lecturing." One hundred and fifty wood engravings illustrate the text.

PRINCIPLES OF MECHANICS. By T. M. GOODEVE, M. A. Lecture on Applied Mechanics at the Royal School of Mines. London. For sale by D. Van Nostrand. Price $1.50.

In this work the author has given an outline of the introductory part of his lectures at the School of Mines, in which he presents a comprehensive view of the principles of mechanics, aiming above all to show the relation of the theory of heat to that science. The contents include not only an exposition of the fundamental principles of mechanics, more or less fully discussed, but also chapters on the mechanical powers, the equilibrium and pressure of fluids and gases, pumps, hydraulic presses and gauges, on girder-beams and bridges, and on some important mechanical inventions.

SANITARY ARRANGEMENTS FOR DWELLINGS. By W. EASSIE, C. E. London. For sale by D. Van Nostrand. Price $2 75.

Mr. Eassie, who is familiar with the questions here raised and discussed, has produced a book which must prove equally useful to officers of health, constructors of houses, and householders. The principal and most usual sanitary defects in dwelling-houses and public institutions in respect to drainage, water supply, ventilation, warming, and lighting, are described, and the most simple and effective means of preventing or remedying such defects set forth. Several paragraphs which had been noted for extract have been kept out by want of space; but the book, which is not an expensive one, will amply repay perusal.

HYDROSTATICS AND PNEUMATICS. By DIONYSIUS LARDNER. Revised and rewritten by BENJAMIN LOEWY, F. R. A. S. London: Lockwood & Co. For sale by Van Nostrand. Price $2.50.

The best elucidation of the principles of Hydrostatics ever afforded to the learner in Physics has been that of Lardner's Natural Philosophy. This treatise has been detached from the main work before and published as a separate volume. We have one before us even now bearing date of 1831, and put up in elegant binding. No work has been so widely recommended to students in this

department of Physics, and none has done such good service.

The revision needed to adapt it to present requirements, was not extensive; but it has been judiciously performed, and we have again an invaluable aid to students and teachers.

THE PRACTICAL ASSAYER. By OLIVER NORTH. London: Chatto & Windus. For sale by Van Nostrand. Price $3.75.

This book affords clear and concise directions to the amateur Assayer, and such as he can follow with success even though he has not acquired skill in the general processes of analytical chemistry. Direct and inexpensive processes are described for assaying Copper, Silver, Gold, Tin, Lead, Iron, Zinc, Mercury, Manganese, Bismuth, Nickel, Cobalt, Sulphur, Arsenic, Sodic Nitrate, and Guano. A few illustrations only are afforded, but perhaps as many as are needed.

A TREATISE ON THE ANALYTIC GEOMETRY OF THREE DIMENSIONS. By GEORGE SALMON, D. D., F. R. S. Dublin: Hodges, Foster & Co. For sale by Van Nostrand. Price $7.00.

A new edition of this excellent work will be gladly received by students of the higher analysis. The present work is just out of the author's hands, the preface bearing date March, 1874. Some important additions by Prof. Cazley are acknowledged by the author. The Appendix, relating to Quaternions, which appeared in the former edition, is omitted in the present one, as the recent treatises on the subject have rendered such an addition to this work unnecessary.

The widely increasing use of Salmon's "Analytical Geometry of Two Dimensions" is the best possible testimony to the value of the mathematical works of this now well-known writer.

EXTINCT VERTEBRATE FAUNA OF THE UNITED STATES. Contributions to the Extinct Vertebrate Fauna of the Western Territories of the United States. By Prof. JOSEPH LEIDY. Government Printing Office, Washington. For sale by Van Nostrand. Price $3.50.

This important volume is the first of five which are to form the "Report of the United States Geological Survey," and it will be supplemented by a memoir, embracing the same subjects, by Prof. Cope.

The large field for paleontological work recently opened up in the Western Territory of the United States has been as fruitful in the introduction of new and unexpected forms of extinct vertebrate life, as that so ably worked out by Cuvier, the Paris basin. By the establishment of a military station at Fort Bridger, opportunities have been afforded to geologists, which the offensive attitude of the Indian tribes had previously deferred, rendering inaccessible a district, the richness of whose past fauna must have been as remarkable as is its present desolation.

Fort Bridger is a military post about 100 miles E. N. E. of Great Salt Lake City, in the southwest corner of the Wyoming Territory. The valley in which it is situated stands nearly 7,000 ft. above the level of the sea at the base of the Uintah Mountains, which form its southern boundary; the Wind River Range defining it on the north-east, and the Wahsatch Mountains on the west separating it from the Great Salt Lake. The enclosed plain is evidently the remains of an extensive fresh-water lake, which in the Eocene period must have abounded with animal life, and whose borders must have been the haunts of animals, both huge and small, which lived and died by its marshy banks. Green River now runs through the plain, and it, with its smaller tributaries, by cutting up the easily eroded deposit, produces a scenery of a most peculiar character, consisting of flat-topped hills and cliffs, with perpendicular sides, and often most grotesque proportions. Those of the watercourses which do not dry up during the summer months are fringed with vegetation, such as cotton-wood, willow and aspen trees; but most of the country is treeless and barren, reminding the spectator more of the ruins of a colossal city, than of any other existing scenery.

The remains of mammals, which are very abundant, are mostly of genera which are not found elsewhere. Several, however, approach those of the Paris Tertiary basin. The odd-toed Ungulata, or Perissodactyla, are particularly numerous, whilst even-toed Ungulate or Artiodactyla are as remarkably few. True Proboscidians are not found, but if Prof. Marsh is correct in placing Dinoceras in an order by itself, animals equally huge, of an independent type, were far from uncommon. Most of the other mammalian orders are most probably represented, though much has yet to be done in the identification of specimens.

The results arrived at by American men of Science show that they deserve the careful study of English paleontologists and geologists, as they have already thrown great light on the fauna of the Tertiary period, and give promise of adding much more to our knowledge of that epoch, so important to the student of the anatomy and classification of the higher vertebrata.—*Abstract from Nature.*

GRIFFITHS' "GUIDE TO THE IRON TRADE OF GREAT BRITAIN." 8vo., pp. 315, illustrated. London: For sale by D. Van Nostrand. Price $10.50.

This is a very excellent work by Mr. Samuel Griffiths, editor of the "London Iron Trade Exchange," and besides supplying a deal of interesting information respecting the Iron and Hardware districts, it contains a general review of our mineral and metallurgical position in relation to the rest of the world, and also apt descriptions of the leading iron works and mineral districts, excellent illustrations of which are also given.

Considering the important position Great Britain holds as an iron-producing country, and as a great centre of trade with the whole world, Mr. Griffiths' figures will be particularly interesting, especially as he thoroughly explains the sources from which the vast supply is drawn, which he estimates to equal 50,000 millions a year, or £ 50,000 for each working day. In addition to describing the original use and present position of our iron districts, the author explains the value of the Bessemer steel system, the uses of the Birmingham and Glasgow exchanges, and gives the reader an insight into the Scotch iron warrant system of storing. Altogether considered, the "Guide to the Iron Trade of Great Britain" is a work of interest and utility, and will no doubt have a large circle of readers. The paper, type and illustrations are all that could be desired, and the binding

substantial, but we advise the addition of an index to future editions.—*Ironmonger.*

A TREATISE ON AN IMPROVED METHOD FOR OVERCOMING STEEP GRADIENTS ON RAILWAYS. By H. HANDYSIDE. London. For sale by D. Van Nostrand, price 40 cents.

Proposes to facilitate the use of steep gradients by utilizing all the power that can be obtained from the steam-pressure, and to devote it entirely to hauling the train without the engine up steep inclines of 1 in 10. In other words, it is proposed to transform the locomotive into a stationary engine, whenever and wherever it may be required, which, in that position, will be enabled to concentrate all its power in drawing up the train of carriages or wagons.—*Building News.*

MISCELLANEOUS.

DYNAMITE EXPERIMENTS. A number of very interesting experiments in blasting with dynamite were recently performed in the vicinity of Rossie Priory, on the estate of Lord Kinnaird, near Dundee. They were conducted at the request of Lord Kinnaird, and in the presence of many gentlemen, by Mr. John Downie, C. E., manager and secretary for the British Dynamite Company. Prior to commencing the experiments, Mr. Downie exhibited the dynamite and the cartridges formed of it, and the detonators and fuses used in its explosion, and he gave a brief account of the composition and properties of dynamite and the mode of using it as a blasting agent. He stated that large quantities of dynamite had been consumed in various Continental countries, in America, in Australia, and in this country, and that no accidents had occurred with it either in storage or in transit. It would not explode of itself, and though set fire to it would burn harmlessly away; even when ignited in a confined space it would still burn harmlessly, although it would expend its power more rapidly than in "the open." When one or two of the cartridges were opened it was found that the dynamite was soft and plastic, and of a reddish-brown color, somewhat similar to raw cane sugar. On applying a burning match to one of the cartridges it burned without any explosion, and left a greyish white residue consisting simply of the fine silicious earth known as kieselgühr, which is the medium in which the power of the really explosive substance, nitro-glycerine, is utilized in blasting. One of the detonators, which is an extra-powerful percussion cap, was fired by introducing a piece of Bickford fuse, and then igniting the free end of the same. A loud report ensued in the course of a few seconds, and Mr. Downie said that a few cartridges fired in a similar manner might be used for producing very loud reports at sea as distress signals.

In order to demonstrate more immediately the practical application of dynamite as a blasting material, to the satisfaction of the spectators, Mr. Downie tried it upon a number of tree roots, the trees themselves having been recently felled purposely for the experiments. By means of a crowbar, a hole was driven through the earth immediately underneath the principal mass of the root; two or three cartridges were thrown into the hole and rammed firmly home by means of a wooden rammer; then the "primer" cartridge, prepared in the usual way with the cap-tipped fuse, was introduced close up to the last cartridge; the opening around the protruding fuse was loosely tamped or stemmed with soil, and then the fuse was ignited. In a minute or two there was an explosion, attended by a low smothered report, and an upheaval of the tree root and the surrounding soil. The whole root was started, split as by wedges, and the ground all around was loosened, and to a considerable extent cleared. When the use of dynamite in blasting the roots of trees for land-clearing purposes was sufficiently demonstrated, the material was tried upon one of a number of very large boulders in an ancient ruin, by some persons regarded as Druidical, and by others as Roman. The dynamite was simply laid upon the top of the boulder, covered with a piece of turf, and fired in the usual way. No bore-hole was employed. The boulder was broken up most completely by the explosion, and started from its ancient seat.

The party afterwards proceeded to Hillton Whinstone Quarry, where a number of workmen were engaged in quarrying and dressing causeway blocks, and preparing whinstone for road-metal and concrete building. After inspecting the wire-rope railway, which was in operation conveying stones from the hill down to the stone-breaking machine in the Den, the party visited the stone-breaker itself, which was found to be driven by water power, and was breaking as much road-metal in a quarter of an hour as a single man could break in a week, and were greatly interested by what they saw. A number of bore holes in the face of the rock, previously prepared for blasting with gunpowder, were charged with dynamite in the usual manner. When the charges were fired, it was found, that at half the expense that would have been required for gunpowder, they had executed as much work as would have required two, three, or four times as much gunpowder or gun-cotton. Various experiments were also performed to show what could be done with dynamite in breaking up blocks of whinstone without making any bore-holes. It may be mentioned that the manipulation in nearly all the experiments after the first was done by some of Lord Kinnaird's own servants.

In the course of the day, Lord Kinnaird stated, that probably few people had had the opportunity of witnessing more blasting operations than he had seen during the time he was acting as a member of the Royal Commission of Inquiry into the condition of the mines of this country in the year 1862. One of the objects of the inquiry was to find a substitute for gunpowder, the fumes of which are very obnoxious and injurious to miners, and, he had no doubt, had dynamite been known at the time, the adoption of it would have been recommended by the Commission, owing to the innocuous character of the fumes resulting from an explosion of dynamite, which resemble those produced by gun-cotton in its explosion, an explosive that could not be recommended on account of its danger in use, and in its conveyance. His Lordship expressed himself as quite satisfied that no safer explosive material was ever brought under his notice; for, in consequence of its inert character, a powerful detonation was required in order to explode it.